PRACTICAL ASTRONOMY
WITH THE UNAIDED EYE

BY

THE REV. HECTOR MACPHERSON
M A., F.R.A.S., F.R.S.E.
MEMBER OF THE SOCIÉTÉ ASTRONOMIQUE DE FRANCE, ETC.
AUTHOR OF "THE ROMANCE OF MODERN ASTRONOMY," "ASTRONOMERS OF TO-DAY," "A CENTURY'S PROGRESS IN ASTRONOMY"

REVISED EDITION

London and Edinburgh:
T. C. & E. C. JACK, LTD. | T. NELSON & SONS, LTD.
1919

CONTENTS.

PRACTICAL ASTRONOMY.

CHAPTER I.

INTRODUCTORY.

WHEN we cast our eyes to the heavens on any clear and, by preference, moonless night, our attention is attracted by apparently innumerable points of light, of all degrees of brightness. These are the stars, which in all ages have drawn to themselves the attention of mankind. Mr. E. W. Maunder, in a previous volume of this series, has shown how man's attention was first directed to the heavenly bodies, and how the mere recognition of the phases of the Moon, the varying positions of the planets and the seasonal changes of the stars has developed stage by stage into the science of astronomy as we know it at the present day.

Perhaps of all the sciences modern astronomy is the most awe-inspiring, the most wonderful, the most instructive. The average man reads of the marvels which the telescope and spectroscope reveal, of the

great depths and spaces, the rapid velocities, the eternal working of evolution, and he wonders. He has little or no knowledge of the methods used by the astronomers in ascertaining the facts of the science; and he is not familiar with the stars or constellations. Let us suppose that there is something unusual in the astronomical world. The newspapers are full of the "opposition of Mars." The average man has read about Mars and he is anxious to see the planet for himself. The almanacs tell him that it is in a certain constellation, say, Virgo, and the newspapers repeat the statements of the almanacs. The would-be observer of Mars is as puzzled as ever. He knows nothing of the constellation Virgo. He does not know where to look for it, and even if he did, he would probably be unable to recognise it. He is paying the penalty for not having made himself acquainted with what we may call the topography of the heavens.

Again, let us suppose that a bright comet is to be seen or that a meteoric shower is expected from a certain constellation, say, Leo. The would-be observer is in the same position as in the case previously mentioned. His ignorance of the topography of the sky is at the root of his inability to see the comet or to witness the meteoric shower.

So much for the utility of knowing the names of the various stars and constellations; but a knowledge of this kind is more than merely useful. No one can really enter into what may be called the spirit of astronomy without having an acquaintance, however slight, with the planets and stars individually. As a contemporary astronomer has well remarked: "How great an interest is given to any object by the fact that we know its name. Take some town children out into the country and set them to gather wild flowers: how instantly they ask their names." It is the same in the case of the stars. When in a clear night we "consider the heavens" and behold apparently countless points of light, we are confused and overwhelmed by the number of the stars and by the complexity of their distribution. One star appears to be almost the same as another, except for the differences in brightness, and we look away from the sky again with neither interest nor curiosity. But if we learn that such and such a star is Aldebaran, and such and such is Sirius, and such and such a constellation is Orion, then our interest in the stars is aroused and as a result we are desirous of tracing out the star groups and of identifying the stars themselves.

"But," the would-be astronomer asks at

this time, "how is it possible for me to learn the names of the stars and trace the outlines of the constellations without being taught?" Carlyle in his old age lamented "Why did not somebody *teach* me the constellations and make me at home in the starry heavens?" But in reality it is not necessary for anyone to be *taught* the constellations. It is best for everyone to *learn* them for himself.

When the would-be astronomer begins his task it may seem almost impossible of attainment, and some of the hints which are given in astronomical books only make the task more difficult. For instance, when we are told to draw imaginary lines through such and such stars in the Plough, and that these will lead us to such and such stars in Bootes and will form triangles and quadrilaterals with such and such stars in Draco, we feel baffled with the magnitude of the task. Again, on some maps and guides to the heavens there are represented what are known as "the constellation figures." On such maps we find the Plough represented by the figure of a bear covered with stars, Cygnus by a star-spangled swan, Orion by a human figure dotted with stars. The stars of all magnitudes are inserted and named, but they are confused and individually lost through the introduction of the constellation figures. These

figures of course are of extreme interest to the historian of astronomy and to the antiquarian. They throw a flood of light on important questions connected with the beginnings of astronomical science, but on star maps intended for the beginner who desires to obtain a knowledge of the topography of the heavens, they are utterly out of place.

The best method of acquiring a knowledge of the stars is to study them as they are, and to obtain a knowledge of the most important constellations in the heavens which it is impossible to mistake. From this it is comparatively easy to trace out the other constellations; to simplify this task by explanation and direction is the aim of the following pages.

Once the observer has become familiar with the various constellations and their seasonal changes a new charm is added to his interest in the stars. As an able astronomer has remarked, the task of learning the stars "has a charm of its own. The silent watchers from heaven soon become each a familiar friend, and to any imaginative mind the sense that he is treading the same path as that traversed by the first students of Nature will have a strange charm."

Our Place in the Universe.—Before entering on the task of describing the topog-

raphy of the heavens, it is necessary to consider briefly our position in the Universe and the bearing of the position and motions of our planet on the appearance of the heavens, and on the apparent motions of Sun, Moon, planets and stars.

We live on the Earth, a globe almost 8000 miles in diameter. This globe is not, as the ancient astronomers believed, suspended in space. It is in ceaseless motion; it turns on its axis once in twenty-four hours, and in addition it revolves round the sun in 365¼ days. The mean distance of the Earth from the Sun is 93,000,000 miles, so the pathway traversed by our world is about 186,000,000 miles in diameter. In order to travel round this great orbit in a year, the Earth whirls through space at the amazing rate of eighteen miles in one second.

But the Earth does not travel alone. It is accompanied on its journey by its faithful satellite the Moon. The Moon revolves round the Earth in a little over twenty-seven days, at an average distance of 238,000 miles. Just as we get our unit of time, a *day*, from the rotation of the Earth on its axis, and a *year* from the Earth's revolution round the Sun, we derive our other unit, the *month*, from the Moon's revolution round the Earth.

The Earth is not, however, the only body

which revolves round the Sun. The orb of day holds sway over a large system of bodies —planets, comets and meteors. The five larger planets are very conspicuous and have been known from prehistoric times—Mercury and Venus within the orbit of the Earth; Mars, Jupiter and Saturn without. In addition there are two distant planets, Uranus, almost invisible to the unaided eye, and Neptune, completely so; and many small planets, between the orbits of Mars and Jupiter, but invisible to the unaided eye on account of their great distance. There are also numerous comets and their kindred bodies, meteors, revolving round the Sun and coming within the reach of human vision from time to time.

The Solar System, so far as we know at present, is a little under 5,000,000,000 miles in diameter, the orbit of Neptune being the known boundary. In this system the Earth is merely one planet among others; and it is by no means the largest. It comes fifth in order of size, being much smaller than Jupiter, Saturn, Uranus and Neptune, and slightly larger than Venus, Mars and Mercury.

The Solar System.—The Sun, the central body of the Solar System, is a huge globe about 866,000 miles in diameter. In volume it is one and a quarter millions of times greater

than that of the Earth, and its mass is 332,000 times that of our planet. The Sun is a great globe of gaseous matter, at an almost inconceivably high temperature. The glowing envelope visible to us—the photosphere—is merely the outer surface. This surface is diversified from time to time by the appearance of sun-spots—great holes or cavities in the photosphere. From these spots it has been ascertained that the Sun rotates on its axis in about twenty-five days; at least this is the period for the equatorial regions, for the vast globe does not rotate as a whole. The spots are not always equally numerous. They increase and decrease in a period of about eleven years. This period is called the solar cycle, and is obeyed by the faculæ, or bright spots on the photosphere, and by the prominences or red flames which are projected from the chromosphere, a thin gaseous envelope surrounding the photosphere. The corona, the outermost appendage of all, varies in shape according to the same period. In addition, the variations of the magnetic needle and of the aurora on earth have a similar period. The discovery of magnetic fields in sun-spots by the American astronomer Hale gives us some idea of the nature of the connection.

The Sun holds sway over a system of bodies

of varying size and condition. We may divide these into two classes: (1) the planetary, and (2) the cometary bodies. The planets fall into three subdivisions: (1) the inner planets; (2) the minor planets, or asteroids; and (3) the outer planets. In addition, two of the inner and the four outer planets are centres of subordinate systems of one or more satellites.

The inner planets are, in order of distance, Mercury, Venus, the Earth, and Mars. Our planet is slightly larger than Venus and considerably larger than Mars or Mercury. Venus and Mercury have no satellites; our Earth has one—the Moon—and Mars has two. Comparatively little is known of Mercury and Venus. Mercury seems to be a barren, rocky world, and it is generally accepted among astronomers that its rotation is performed in eighty-eight days, the same period as is required for its revolution round the Sun. One hemisphere, accordingly, experiences everlasting day and the other perpetual night. Many astronomers accept a similar conclusion in regard to Venus, but the evidence is not so strong. The atmosphere of Venus is very thick and cloud-laden, and very few of its surface-markings are known.

Mars, on the other hand, rotates on its axis in about twenty-four hours thirty-seven minutes. The atmosphere of Mars is con-

siderably thinner than that of our Earth, and its surface-markings have been mapped for two centuries. The disc is diversified by reddish-ochre and blue-green areas, while at the poles there are white spots which wax and wane in accordance with the Martian seasons. The reddish-ochre regions, from which the planet takes its ruddy tint, are known to be deserts, and the blue-green areas marshy tracts of vegetation, while the polar caps are composed of snow and ice. In 1877 Schiaparelli, at Milan, discovered the remarkable "canal" system which for the last forty years has attracted so much attention. The whole surface of Mars is cut up by a system of straight dark lines, which vary according to the seasons. Many theories have been put forward to account for the canal system. At present the balance of evidence is in favour of the theory of the late Professor Lowell of Arizona, based on his study of the planet for twenty-two years—that the canal system is artificial and indicates the existence of intelligent life on our neighbouring world.

Mars appears to represent a later stage in planetary development than our Earth. The Moon is at a still later period. Long-continued study of the Moon has convinced astronomers that it is practically a dead world. Professor W. A. Pickering's researches have

led him to the conclusion that there is a very thin atmosphere, and that vegetation of a low order still exists. But the existence of animal life is highly improbable. The lunar rotation is performed in exactly the same period as its revolution round the Earth. One hemisphere is continually turned towards us, and the other side has never been seen.

The asteroids, a group of about 800 tiny planets, revolve between the orbits of Mars and Jupiter. The largest, Ceres, is about 400 miles in diameter; the smallest are very minute. A very tiny asteroid, discovered by Max Wolf early in 1918, has a diameter of only four miles.

The four outer planets—Jupiter, Saturn, Uranus, and Neptune—are very much larger than the Earth and its neighbouring worlds. The largest, Jupiter, is nearly 90,000 miles in diameter. All four seem to be in a condition of great internal heat, and it is doubtful if solid surfaces exist below their heavy cloud-laden atmospheres. Jupiter has nine satellites—four large and five small; Saturn ten; Uranus four; and Neptune—so far as is known—one. In addition, Saturn is encircled by a wonderful system of rings, composed of myriads of tiny meteorites revolving so closely together as to be individually indistinguishable from our world.

A considerable number of comets are known

to be members of the Solar System, revolving round the Sun in very elliptical orbits. These comets are not solid bodies like the planets, but appear to be collections of loose stones, surrounded by gaseous matter. Meteors, or shooting-stars, are believed to be the products of the dissolution of cometary bodies.

Let us suppose that the Solar System, which is both absolutely and relatively of so vast an extent, were co-extensive with the visible universe—in other words, let us imagine for the sake of clearness that the Universe were no larger than the Solar System. It would be indeed a very large universe, much larger than we are able to comprehend. The Sun would rise and set as at present; it would ascend to its highest point in summer and descend to its lowest point in winter. The Moon would pass through its cycle of changes in its revolution round the Earth. The planets would make their periodical appearances, shining brilliantly on an inky black sky. Usually there would be some object visible in this black sky; on moonless nights one or two planets would probably be seen, but there would be evenings on which the heavens would be absolutely black. For there would be no stars.

Thus by imagining the heavens without stars, we are enabled at once to assign to the

stars their true position in the order of nature. The stars are luminaries far outside of the Solar System; the stars, in fact, are not worlds in any way analogous to the planets; they are themselves suns similar to the central body of the Solar System. It is true that when we see a planet on the background of stars it appears much more brilliant. Jupiter, for instance, shines many times more brightly than Sirius, the brightest of the stars; and yet Jupiter in comparison with even the faintest star which we see twinkling in the field of the telescope is utterly insignificant. It belongs altogether to an inferior order of bodies; it is merely the attendant of a star. Thus we see that one effect of the great distance of the stars is to make them seem very insignificant bodies.

Another effect of their distance is that their motions are to the ordinary observer absolutely imperceptible. One of the great truths of modern astronomy is that the so-called "fixed" stars are in motion in various directions and with different velocities; but so great is their distance that these motions can only be noted after the lapse of many years, with the aid of powerful instruments and exact measurements. Were Homer or Hesiod or the author of the Book of Job alive to-day, they would see the same constellations and

stars with which they were familiar. They would behold apparently unchanged the "bands" of Orion and the Pleiades and "the Bear with her train."

Thus to us the stars are the background of the Solar System—the setting to the drama of the planetary motions. And as such the stars were treated for many years. They were observed mainly as convenient reference-points for the observation of the positions of the Moon and planets. Since the days of Sir William Herschel, however, the stars have been observed and studied for their own sake.

The stars then are the distant background of the Solar System. Thus when we read in astronomical almanacs or in the newspaper press that "Mars is in Aries" or "Jupiter is in Taurus," it is necessary for us to remember that seen from the Earth, Mars is in the same line of vision as the stars in the constellation Aries; that the constellation Taurus is the background against which Jupiter is seen.

We must also bear in mind that the stars are not a real background, but only an apparent one. The constellation Taurus, for instance, is not a collection of bodies all at the same distance from the Solar System. Some of the stars in the constellation form connected groups and systems, but the constellation is not necessarily a unity. In

other words, the stars are at different distances. Sirius, for instance, the brightest star in the sky, is much closer to the Earth than Rigel in the neighbouring constellation.

The stars are at various distances. To make this clear, a simple illustration may be given. Two stars, let us say of equal brightness, appear close together in the heavens. They may form a connected system, but not necessarily. One may be much closer to the Solar System than the other, and they may appear close together merely because they happen to lie in the same line of vision. It is quite a mistake to suppose that the brightest stars are necessarily the nearest. Sometimes they are so, sometimes they are not. For instance, an insignificant star of the fifth magnitude in the constellation Cygnus is nearer to the Earth than Sirius, the brightest star in the sky.

Distance of the Stars.—Something remains to be said of the distance and magnitude of the stars. We have seen that the diameter of the Solar System is a little under 5,000,000,000 (five thousand million) miles. The principle of the measurement of star-distance has been explained by Mr. Maunder in another volume of this series, and it is only necessary to give one or two examples of the distances of the stars. The nearest star is

only visible in the southern hemisphere. It is the brightest star of the constellation Centaurus and is known as Alpha Centauri, and the distance of this orb is about twenty-five billions of miles. It is almost impossible to realise this vast distance, but an idea may be gained from consideration of the fact that if the distance from the Sun to Neptune, the most distant planet of the Solar System, were represented by 10 feet, the nearest star would be fourteen miles away. The great distance of the stars may be better realised in another way. The rays of light, which travel from the Moon to the Earth in a second and a half, with a velocity of 186,000 miles per second, cross the diameter of the Solar System in eight hours. Four years are required for light to travel from the nearest star.

Magnitudes of the Stars.—The stars, as we have seen, are situated at all distances from the Solar System, and probably they are of all sizes. Yet their apparent brilliance does not on the whole depend on distance or size alone, but on both. One bright star may be comparatively near and of moderate size, another may be very distant and of immense dimensions. The stars are divided into *magnitudes* according to their apparent brightness ; and six magnitudes of stars are within reach of the unaided eye. There are

about twenty stars of the first magnitude and sixty of the second. Some of the constellations, as will be explained, are very rich in bright stars, others very poor.

The brightest stars have proper names. Thus the brightest star of Canis Major is known as Sirius, and the brightest star of Taurus is known as Aldebaran. These proper names were given to the stars by the early astronomers, Greek and Arabian. When the stars came to be catalogued and charted it was necessary to designate them individually. Accordingly the brighter stars in each constellation are known by the letters of the Greek alphabet. Thus Aldebaran is also Alpha Tauri (literally Alpha of Taurus, "Tauri" being the Latin genitive), Sirius is Alpha Canis Majoris. When the Greek letters become exhausted, numbers are used.

The Stellar Universe.—Just as the Earth and the other planets form a system of worlds revolving round the Sun, so the Sun and the other stars also form a connected system on a much vaster scale. While the planets are separated by millions of miles, the distances between the individual stars are to be reckoned by billions.

Much information has been collected concerning individual stars—their distances and masses—and concerning double and variable

stars. But two important generalisations stand out clearly. The stars are aggregated towards the Milky Way or Galaxy. If we compare the Stellar System to a great globe, the Galaxy may be likened to its equator. There is a progressive increase in the number of stars as the Galaxy is approached, and the galactic region seems to be both a region of greater condensation and of greater extension in the line of sight. Some of the distant star-clouds of the Galaxy are so far away that light requires thousands of years to travel to the Earth.

Another important generalisation has been established in recent years by the researches of Kapteyn, Eddington, Dyson and others. The motions of the great mass of the stars—as far as is at present known—are not at random; there is a drift of the stars in two well-defined directions. Various hypotheses have been put forward to account for this, but no satisfactory conclusion has yet been reached. One point is clear—there is no "central sun" among the stars: the Stellar System is not analogous to the Solar System. Flammarion, in one of his happy illustrations, compares the Solar System to an absolute monarchy with the Sun as despot, and the system of the stars to a federal republic with no dominating authority.

It has been computed that there are in the Stellar System about 500,000,000 stars, and

several thousands of gaseous nebulæ; but, nevertheless, it appears to be strictly limited in extent. Like the Solar System, this greater Stellar System seems to be merely one among others. Recent research makes it probable that some of the isolated star-clusters and many of the spiral nebulæ are external, though probably smaller and perhaps dependent, systems plunged at vast distances in space. It has been computed that the cluster in Hercules, one of the nearest, is situated at a distance so great that light requires 100,000 years to travel.

We are confronted then with an ascending scale of world-systems. First of all, we have the little terrestrial system—the Earth and Moon—and other satellite systems within the greater Solar System; secondly, the Solar System is merely one of millions of other systems, components of the greater Stellar System; thirdly, the Stellar System—vast, almost infinitely vast in extent though it be—appears to be but one of a number of similar systems scattered throughout the infinite extent of space. The human mind is unable to conceive this apparently endless profusion of suns and systems and systems of systems. We pause awe-stricken before what Shelley a century ago called

> "This interminable wilderness
> Of worlds, at whose immensity
> Even soaring fancy staggers."

We are face to face with infinity—the eternal, the illimitable, the unthinkable. In the words of the poet Richter, "The spirit of man acheth with this infinity"; for "end is there none to the Universe of God. Lo! also there is no beginning."

CHAPTER II.

THE NORTHERN STARS.

THE positions of the stars in the sky are subject to two periodical changes—the hourly change and the seasonal change. The former is due to the rotation of the Earth on its axis and the latter is due to its revolution round the Sun. Even the casual observer can see that the stars rise and set like the Sun and that different stars are visible at different seasons.

Owing to the rotation of the Earth on its axis the entire star-sphere appears to move round our world once in twenty-four hours; and owing to the revolution of the Earth round the Sun, the orb of day appears to move among the stars, or rather, the stars appear to drift westward into the sunset, rising and setting four minutes earlier each night.

The Earth rotates on an axis which is

inclined to the plane or level of the terrestrial orbit round the Sun by about sixty-seven degrees, and to the perpendicular by about twenty-three degrees. The result is that some stars rise and set like the Sun, others are never to be seen, while others again neither rise nor set, but seem to circle round a fixed point in the sky, and are continually visible whenever the sky is clear and the Sun absent. In a survey of the heavens, it is wise to commence with the stars which are continually visible—the circumpolar stars of the northern hemisphere.

The Plough.—The axis of the Earth points to a part of the heavens very close to a bright star of the second magnitude known as the Pole Star, which remains practically stationary in the heavens. But the Pole Star is not the most suitable object from which to commence a study of the circumpolar stars. There is no question that the large constellation of *Ursa Major*, or the Great Bear—or a part of it—is the conspicuous object of the northern heavens. No one can mistake the seven stars known variously as the Plough, Charles's Wain and—in America—the Dipper. These stars have been noted and observed from the earliest ages ; they are referred to by Homer and Hesiod and in the Book of Job.

The Plough is seen to best advantage in

autumn, when it is due north and comparatively low down in the heavens; there can then be no difficulty in identifying the group. The northern heavens are not especially rich in bright stars, and in the autumn evenings the Plough is visible either slightly tilted to the north-west, due north, or slightly tilted to the north-east, according to the hour of the night or the time of the season. For instance, at ten o'clock in the beginning of

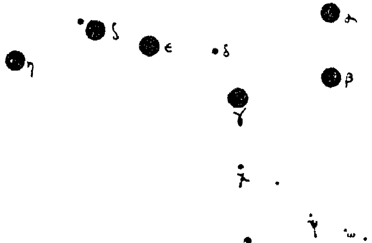

FIG. 1.—The Plough.

October the Plough is directly north, a month later at the same hour it is slightly tilted to the north-east; but it is unnecessary here to mention the various days and hours on which the Plough is to be seen in different positions. Once the configuration of the constellation is implanted in the mind, there will be no difficulty in picking it out, whatever its position.

In the winter evenings, generally speaking, the Plough is in the north-east ascending in

the heavens. As the hours pass on during the same evening, or as the season progresses at the same hour, the Plough rises higher and higher in the heavens until in spring it is practically in the zenith in the hours fitted for observation. This is the season when it is most difficult to recognise the Plough. If, however, we are familiar with it before, it is quite easy to identify the well-known figure high in the sky. In summer, the Plough is to be seen in the north-west, descending as the season advances.

On the whole it may safely be said that the autumn is the best season for a beginner, who knows nothing of the constellations and has never seen the Plough, to commence his studies. Obvious at all times, the Plough is absolutely unmistakable in the autumn evenings. There are seven stars in the constellation, six of which are, roughly speaking, of the second magnitude and one of the fourth. Proceeding from the front of the Ploughshare backwards to the handle, the stars are designated by the first seven letters of the Greek alphabet—Alpha, Beta, Gamma, Delta, Epsilon, Zeta, and Eta. They are also known by Arabic names. Alpha is "Dubhe," Beta is "Merak," Gamma is "Phecda," Delta is "Megrez," Epsilon is "Alioth," Zeta is "Mizar," and Eta is "Alkaid" or "Benet-

nasch." Of these names, only the sixth, Mizar, is commonly used.

Two of the stars in the Plough call for special mention, Delta and Zeta. Delta is generally believed to have been at one time of the second magnitude, whereas it is now of the fourth, so it would seem to have decreased in brilliance. Zeta, generally known as Mizar, is a remarkable star. A keen eye can detect the fact that it is double, or rather that there is a faint companion star near. This little star is known as Alcor, and in the binocular the two make a striking spectacle. With a moderate telescope Mizar is seen to be itself double.

The Plough is only part of the constellation Ursa Major, but it is much the more conspicuous part. The remaining stars of the constellation are much fainter, and much more difficult to trace.

The Pole Star.—Alpha and Beta of Ursa Major are known as "The Pointers," because a straight line joining these two stars points directly to the Pole Star. Once these two stars are known, it is impossible to mistake the Pole Star. It is noticeable as being the next conspicuous star in the line with the Pointers. As its name indicates, the Pole Star approximately marks the point in the heavens to which the Earth's axis points. To an observer at the North Pole, the Pole

Star would appear almost exactly overhead; to an observer at the equator, it would seem almost exactly on the horizon. In our latitudes, the altitude of the Pole Star above the horizon varies with the latitude of the place from which it is observed. To the ordinary observer, the star seems stationary in the heavens, the one point around which the other stars describe circles. In reality its position does not exactly coincide with the celestial Pole; it actually describes a very small circle, and there are several stars nearer to the Pole, which are practically invisible without the aid of a binocular—the chief of these being Lambda of Ursa Minor, which is just visible to the unaided eye.

The Pole Star is the chief star of *Ursa Minor* or the Little Bear, and is also known as Alpha Ursae Minoris. The constellation Ursa Minor, like the more conspicuous Ursa Major, has seven principal stars. Proceeding in a curve from the Pole Star these are Delta, Epsilon, Zeta, and Beta; while Gamma and Eta form a square with Beta and Zeta. Beta and Gamma are the only noticeable stars of the constellation except the Pole Star.

Cassiopeia. — Once the Plough and the Pole Star have been identified, the task of learning the arrangement of the northern stars is much simplified. If we keep the

Plough and the Pole Star in view it is easy to identify another notable constellation. On the exactly opposite side of the Pole Star from the Plough and at about the same distance is a star-group almost as conspicuous, though smaller than the Plough itself. This is *Cassiopeia* or the Lady in the Chair. The shape is easily remembered; it is like the letter W. In the evenings of spring-time, when the Plough is almost overhead, Cassiopeia is visible low down in the north. It is then to be seen to the best advantage and its W-shape is most obvious. In summer, when the Plough is descending to the north-west, we see Cassiopeia ascending in the north-east. In autumn, when the Plough is low down in the north, Cassiopeia is almost exactly overhead; and in winter, when the Plough is ascending in the north-east, Cassiopeia is descending in the north-west. Small though it is in extent, Cassiopeia is one of the most prominent constellations in the sky on account of the brightness of its stars and its symmetrical shape. Beginning at the right-hand corner of the W-shaped figure, the five chief stars are Beta, Alpha, Gamma,

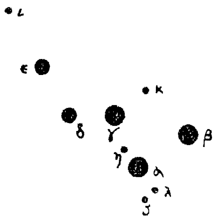

Fig. 2.—Cassiopeia.

Delta, and Epsilon. Beta, Alpha, and Gamma are of the second magnitude, and Delta and Epsilon are of the third. Kappa, though faint—of the fourth magnitude—is prominent by reason of its position. It forms a trapezium with Beta, Alpha, and Gamma. Another faint star which is easily identified by reason of its position is Iota, which is in a straight line with Delta and Epsilon.

The constellation is one of the richest in the heavens, and in this it differs from its companion star-group, the Plough. Ursa Major is situated in a barren portion of the sky. Cassiopeia is fully immersed in the stream of the Milky Way or Galaxy. The Milky Way is one of the best-known celestial phenomena. As Mr. Maunder has explained in a previous volume of this series, the Milky Way is the "foundation of the celestial building." It is the ground-plan of the Universe. It is nothing more nor less than the region of the heavens in which the stars are most closely crowded together. To the unaided eye it presents the appearance of a belt of milky light across the sky; and in this belt, not at the broadest, but at one of its brightest parts, the chief stars of Cassiopeia are immersed. To the observer with a binocular, Cassiopeia is a particularly interesting field for observation. The star Gamma is the centre of one

of the most remarkable regions in the heavens in regard to the symmetrical arrangement of the stars ; it is also very crowded.

The constellation is also famous in the history of astronomy owing to the fact that the most brilliant temporary star which has been recorded shone out near Kappa in August 1572. This star was particularly studied by the famous astronomer Tycho Brahe, who, although he did not discover it, observed it so patiently and systematically and left so complete an account of its variations that it has always been known as "Tycho's Star." One evening in November 1572 the astronomer, on casting his glance upwards, was astounded to notice the familiar appearance of Cassiopeia completely changed by the presence of a new and brilliant star which far outshone the other stars in the constellation. When first seen by Tycho it was as bright as Jupiter, and when it reached its maximum it was equal to Venus in brilliancy, being visible in full daylight. Steadily declining, it ceased to be visible to the unaided eye a year and a half after its appearance.

Capella and Vega.—Having identified the Plough, the Pole Star and Cassiopeia, it is comparatively easy for the observer to find the other important northern stars. As already mentioned, the Plough and Cassiopeia

are on opposite sides of the Pole Star. There are two stars, also on opposite sides of the Pole, which are useful guiding stars not only for the northern heavens but also for the stars which rise and set. On account of their brilliance, Capella (Alpha Aurigae) and Vega (Alpha Lyrae) cannot be mistaken; and although these are—at least in Scotland—circumpolar stars visible all the year round, *Auriga* and *Lyra* cannot properly be described as circumpolar constellations. Capella is the prominent star of the first magnitude between Cassiopeia and the Plough. In the autumn, when the Plough is due north and Cassiopeia nearly in the zenith, Capella is ascending in the north-east. In winter, when the Plough is ascending in the north-east and Cassiopeia descending in the north-west, Capella is to be seen almost overhead, while Vega is practically lost in the haze of the horizon. In spring, when the Plough is nearly overhead and Cassiopeia low down in the north, Capella is descending in the north-west and Vega ascending in the north-east. In summer, when the Plough is descending in the north-west and Cassiopeia ascending in the north-east, Vega is nearly overhead, while Capella is practically lost in the haze of the horizon.

Vega and Capella will be more fully described in the chapters on the summer and

winter constellations respectively; but it is essential that these two stars should be known soon after the Plough and Cassiopeia.

Cepheus.—There are other two northern constellations, less conspicuous than those mentioned, which it is well to identify. These are *Cepheus* and *Draco*. The former constellation adjoins Cassiopeia. When Cassiopeia is low down in the north Cepheus is above Cassiopeia to the right, and practically immersed in the stream of the Milky Way.

The stars Alpha, Beta, Iota and Zeta form a well-marked trapezium. All four are of the third magnitude. Within the trapezium and nearly in the centre is Xi Cephei, of the fifth magnitude. Gamma Cephei forms a triangle with Iota and Beta; it is of the third magnitude and comparatively close to the Pole Star, with which it is in line. Another much smaller triangle is formed by Zeta, Epsilon and Delta. Delta is a variable star—the brightest of the important and numerous class known as "Cepheids." It varies from the third magnitude to the fourth in 5 days 8 hours 7 minutes 40 seconds. Mu Cephei, of the fourth magnitude, lies between Alpha and Zeta, below an imaginary line joining them. It is probably the reddest star visible to the unaided eye in the northern hemisphere, and was named by Sir William Herschel "the

garnet star." Seen in the binocular, Mu Cephei is a very striking and beautiful object.

Draco is one of the most difficult constellations to follow. It adjoins Cepheus and winds along the barren reaches of the sky near Ursa Minor, and ends in a line of stars parallel to the Plough—Alpha, of the third magnitude, is on a line with Zeta Ursae Majoris (Mizar), Lambda is on line with Alpha Ursae Majoris; while Kappa is the star between Alpha and Lambda. The constellation coils round the sky until it joins Cepheus; then it curves round again and terminates in three bright stars Xi, Beta and Gamma near the boundaries of the constellation Hercules. These three stars with Iota Herculis form a diamond-shaped figure.

There are other constellations partly circumpolar—Cygnus, Perseus and Andromeda, but these are practically invisible at certain periods and will be discussed among the stars of the respective seasons.

We have now completed a survey of the northern stars which are visible all the night and all the year round. Beginning with the Plough, the observer will recognise the Pole Star and Cassiopeia, and by means of these he will identify Capella and Vega, the two watchers of the northern heavens. There is something awe-inspiring in contemplating the

ceaseless revolution of these stars, and this feeling is not diminished by the recollection that the motion we are watching is that of our own world projected on the sphere. As an able writer has expressed it: "To watch these northern constellations as they follow each other in regular ceaseless procession round the Pole is one of the most impressive spectacles to a mind capable of realising the actual significance of what is seen. We are spectators of the movement of one of Nature's machines, the vastness of the scale of which and the absolutely perfect smoothness and regularity of whose working so utterly dwarf the mightiest work accomplished by man."

CHAPTER III.

THE STARS OF WINTER.

In the previous chapter a description was given of what are known as the circumpolar stars—those stars in the northern heavens which are situated so close to the Pole that they do not rise nor set, but circle ceaselessly round. They are to be seen every clear night, in positions varying with the changing seasons.

The majority of the stars, however, are not thus situated. They have their seasons of

visibility and invisibility, of favourable and unfavourable positions, depending on two factors—their apparent distance from the Pole and their position with respect to the Sun. As mentioned in the previous chapter, as the distance of a star from the Pole increases, the circle which it describes grows wider and wider. Some constellations, such as Perseus, Andromeda and Auriga, are partly circumpolar partly seasonal. The circles which they describe only pass very slightly below the northern horizon. Other constellations, such as Gemini and Bootes, pass below the horizon for a slightly longer period; but such groups always rise in the north-east and set in the north-west. Other groups farther from the Pole, such as Orion, rise almost due east and set almost due west; while others again merely ascend a little distance above the southern horizon, rising in the south-east and setting in the south-west.

Owing to the apparent motion of the Sun among the stars, or, as it appears to us, the apparent drifting of the stars into the sunset twilight, these stars which rise and set have their particular seasons of visibility. The nearer the constellation is to the Pole the longer its period of visibility. For instance, Auriga only disappears from view for a short time. The farther a constellation is from the

Pole, the shorter the period during which it is visible. This is the case with Canis Major, Lepus, Scorpio and other groups which never rise far above the southern horizon.

Even those stars which are visible almost all the year round are seen to most advantage in certain seasons; and the easiest way to learn the various star groups is to discuss them season by season.

We begin with the stars of winter, for two chief reasons. In the first place, the winter-time is the season when astronomical observation is easiest. The long dark evenings are the most favourable for the study of the heavens. In the second place, the winter constellations are the most brilliant and most easily identified. It is a curious fact that the stars visible in the winter months are far more beautiful and striking than those to be seen in spring, summer or autumn. As Flammarion has truly remarked: "Nature everywhere establishes harmonious compensation, and whilst it darkens our short and frosty days it gives us long nights enriched with the wealthiest creations of the heavens."

Orion.—In some guides to the stars directions are given to identify the brilliant winter stars by means of lines drawn from the Plough or Cassiopeia. In reality no such method is necessary; for *Orion*, the leader of the winter

constellations, is the most brilliant of all the star-groups, and is always visible at a convenient altitude for observation. It rises almost due east, culminates midway between the horizon and the zenith, and sets almost due west. Once seen, Orion can never be forgotten. In the early evening in November and December, it is visible rising in the south-east; later in the season it reaches the meridian, or point due south. In February and March it is descending in the south-west.

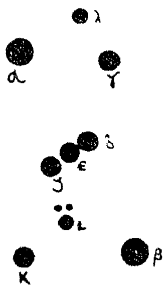

FIG. 3.—ORION.

A large proportion of people, who have no particular interest in astronomy, are familiar with Orion. The figure is easily remembered. An irregular quadrilateral is formed by the four bright stars, Alpha, Gamma, Beta and Kappa. In the centre of this quadrilateral are three stars almost equally bright, nearly in a straight line slanting downwards. These are Delta, Epsilon and Zeta.

Of these seven stars two, Alpha and Beta, are of the first magnitude, and five, Gamma, Kappa, Delta, Epsilon and Zeta, of the second. Alpha, at the north-east or top left-hand corner of the quadrilateral, is more familiarly known by its Arabic name Betelgeux. It is a very

conspicuous object, shining with a red light which contrasts with the bluish-white radiance of Rigel. Generally, Betelgeux is inferior in brilliance to Beta Orionis, more commonly known as Rigel, the star in the south-west, or the bottom right-hand, corner of the quadrilateral; but at times it increases in brightness and outshines Rigel. Its variations are irregular, but easily followed. It is generally believed to have been brighter than Rigel in 1603, when the Greek letters were assigned to the individual stars. At that date it was designated Alpha, indicating that it was then the chief star of the constellation.

These two stars, Betelgeux and Rigel, have been much studied by astronomers. Both are so far distant from the Earth that it cannot be said that the attempts to measure their distance have met with success. Approximate measurements, however, have been made. Betelgeux is at least over 20,000 times more massive than the Sun. It is, as already mentioned, a red star, as its atmosphere is much heavier than that of our orb of day. As the subject of spectroscopic astronomy is dealt with in another volume of this series, it is unnecessary to mention the methods by which astronomers have reached their conclusions concerning these stars. Betelgeux is, as already mentioned, a variable star; and vari-

able stars of this particular type are generally red in colour.

Rigel, on the other hand, is bluish-white in colour, shining with a clear light. Its only points of resemblance to Betelgeux are its immense distance and enormous size. Its distance cannot be measured, but astronomers have calculated the minimum distance at which it can be placed. It is placed, even on the minimum estimate, at a distance so vast that light, which travels from the Sun in 8 minutes and from the boundaries of the Solar System in 4 hours, requires no less than 307 years to cross the mighty void. It must be a sun of enormous size, probably one of the greatest bodies in the entire Universe; its mass is at least 37,000 times that of the Sun, and, as we know, the Sun is inconceivably larger than the Earth.

Gamma Orionis, in the north-west or top right-hand corner of the quadrilateral, is frequently known by its Arabic name Bellatrix. At the south-east corner of the figure is Kappa, also of the second magnitude.

The most famous object in the constellation is, however, the Great Nebula in Orion. It surrounds Theta Orionis, the middle star of the "Sword of Orion," which consists of three faint stars in a straight line with Epsilon, the middle star of the belt. On a clear night a keen eye can detect a haziness about Theta

which a binocular shows to be a cloud of misty light. Even in a small telescope it is a striking spectacle. The haziness expands into a magnificent cloud-like object, and its apparent size increases as the telescope employed becomes larger. The nebula is a gigantic mass of glowing gas, thousands of times larger than the Solar System. Photography has shown the nebula to be vastly more extended than it appears to be when studied with the telescope; indeed the whole constellation has been ascertained to be wrapped in nebulous haze.

Orion, as the most conspicuous of the constellations, has been known from the earliest ages and is referred to by the early writers. Homer refers to Orion, while we are all familiar with the well-known passage in the Book of Job, "Canst thou loose the bands of Orion?"

Canis Major and Canis Minor.—Orion is the index-constellation of the winter star-groups in the southern aspect of the heavens. Betelgeux forms a very conspicuous equilateral triangle with two other bright stars, Sirius in *Canis Major* and Procyon in *Canis Minor*. As the old rhyme has it:

"Let Procyon join to Betelgeux and pass a line afar,
To reach the point where Sirius glows, the most conspicuous star,
Then will the eye delighted view a figure fine and vast,
Its span is equilateral, triangular its cast."

The great triangle is one of the most noticeable configurations in the entire heavens; its striking appearance being due to the brilliance of the three stars composing it and to the dearth of stars within. Procyon, a star of the first magnitude, is the chief star—Alpha—of Canis Minor or the Little Dog. It is the only conspicuous star in an inconspicuous constellation. More striking in its appearance is Canis Major or the Great Dog. This group is famous as containing Sirius—Alpha Canis Majoris—the brightest star in the sky. Sirius is never to be seen very high in the heavens in these latitudes, rising in the south-east and setting in the south-west. The "Dog Star" has been termed "the monarch of the skies," and so far as mere brilliance is concerned fully merits the title. Much of its brilliance, however, is due to the fact that it is comparatively one of our nearer neighbours in space. Light requires eight years to reach us from the Dog Star, as compared with hundreds of years from Betelgeux and Rigel. Therefore, although Sirius is probably considerably larger than our Sun, it is relatively a small star in comparison with other orbs which appear its inferiors on account of their greater distance. Sirius is a well-known double star, but the satellite can only be seen in powerful telescopes.

Taurus.—Higher in the sky than Orion are

two brilliant constellations, Taurus and Gemini. It is impossible to mistake the two groups. *Taurus* is north-west of Orion, Gemini north-east. Taurus is the second of the twelve constellations of the Zodiac, through which the Sun moves on its apparent path round the Earth, while Gemini is the third. Of the two Taurus is the more famous, as it contains the two well-known star-clusters, the Hyades

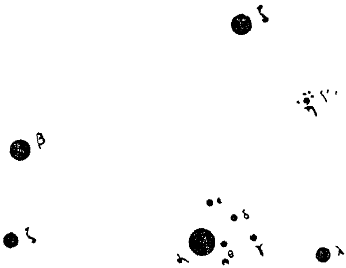

FIG 4.—TAURUS.

and the Pleiades. The former is a group of five stars arranged like the letter V. The brightest star of the Hyades, and indeed of the constellation, is Aldebaran or Alpha Tauri, which marks the upper left hand of the figure. Epsilon, of the fourth magnitude, marks the upper right hand, and Gamma, also of the fourth magnitude, the angle. Aldebaran is by far the most conspicuous star; it is of a bright red colour and indeed closely resembles

Betelgeux in the neighbouring constellation. The distance of Aldebaran has been measured with some approach to certainty, and its mass is believed to be about two hundred times that of the Sun.

The Pleiades.—Higher in the sky than Aldebaran and the Hyades, and on the right-hand side of these stars, is the most famous star-cluster in the entire heavens—the Pleiades. Like the Plough and Orion, this cluster has attracted the attention of man from prehistoric times. "Canst thou bind the cluster of the Pleiades ?" asks the Creator of Job in that Book of the Bible.* Hesiod too says of the Pleiades,

> "There is a time when forty days they lie
> And forty nights, concealed from human eye,"

referring to their invisibility when the Sun is passing through Taurus.

The Pleiades begin to appear in the late evenings of autumn, above the eastern horizon. At this season we, like Tennyson's hero of *Locksley Hall*, behold

> ". . . the Pleiades rising through the mellow shade
> Glittering like a swarm of fire-flies tangled in a silver braid."

The name "Pleiades" is probably derived from the Greek "Pleiones," *many* or *full*. The stars are closely packed together. Six

* Revised Version.

stars, the brightest of which is Alcyone, or Eta Tauri, are visible to a person of average sight, but a very keen eye will discern as many as twelve or fourteen. The binocular changes the entire aspect of the cluster, revealing many more stars, while in the telescope many hundreds may be seen. Since the invention of the telescope the cluster has received its full share of attention. The photographic plate has shown it to consist of thousands of stars; and not the least interesting of the revelations of photography has been the discovery that the group of the Pleiades is not a cluster pure and simple, but that the stars composing it are embedded in nebulæ, masses of incandescent gas. The cluster seems to be in a chaotic condition, and the stars composing it are generally considered to be at an earlier stage of evolution than our own Sun.

Gemini.—Next to Taurus, and to the left of Orion, is the constellation *Gemini* or the Twins. Gemini is chiefly notable for the two bright stars, Castor and Pollux, on the eastern boundary of the constellation. Castor is designated as Alpha Geminorum and Pollux as Beta Geminorum. Here we have a case similar to that of Alpha and Beta Orionis; Pollux is brighter than Castor. It is generally believed that Castor has decreased in brilliance since the stars received their Greek letters.

Castor is a double star, but is not within the reach of the binocular. On the right-hand side of the constellation is a square formed by four stars Epsilon, Mu, Gamma and Zeta. Epsilon and Mu are of the third magnitude and Gamma of the second; while Zeta is a well-known variable, fluctuating from the third to the fourth magnitude in 10 days 3 hours. It can be easily followed with the unaided eye or binocular. Zeta forms an equilateral triangle with other two stars, Delta of the third magnitude and Lambda of the fourth. Finally, close to Mu is a noticeable star Eta, of the third magnitude although slightly variable.

Lepus and Eridanus.—Returning to Orion, it is well to note the inconspicuous constellations close to it, *Lepus* and Eridanus. Lepus —the Hare—is exactly underneath the magnificent star group. There is nothing remarkable about this constellation; its four chief stars, Alpha and Beta of the third magnitude and Gamma and Delta of the fourth, form the corners of an irregular quadrilateral. *Eridanus* is a much less compact constellation. It straggles from close to Orion to the boundaries of Cetus, and then curves downwards into the southern hemisphere. Beta Eridani, of the third magnitude, can be easily identified from its proximity to Rigel.

Auriga.—A survey of the winter constella-

tions is incomplete without reference to one of the most remarkable of all, namely *Auriga.* Starting from Orion, the guiding constellation of winter, it is easy to recognise Auriga. Above Orion, as we have seen, are Taurus and Gemini, the bright stars of which are on either side of the space immediately above Orion. Above these two, and therefore directly above Orion and almost in the zenith, is Auriga. This group, which, as mentioned in the preceding chapter, is almost a circumpolar constellation, is of the shape of an irregular pentagon, with one of its sides much shorter than the rest. The stars forming the corners of the figure are Alpha or Capella, Beta, Theta, Iota and Epsilon. Capella is of the first magnitude and one of the most brilliant of all the stars. It is a star of the same type as our Sun, only very much larger and more massive; in recent years, it has been found by means of the spectroscope to be an exceedingly close double star. Beta, of the second magnitude, has also been found to be double by the same method. Theta, Iota and Epsilon are of the third magnitude, but do not call for special mention. Epsilon forms an isosceles triangle with Eta and Zeta, two stars of the fourth magnitude very close together. In Auriga appeared the famous "new star" of 1891.

Perseus.—To the right of Auriga and further along the stream of the Galaxy, which here becomes more brilliant, is the well-known constellation *Perseus.* This group, one of the most fascinating in the entire heavens to the beginner, is very easily identified. Its most notable feature is a triangle, almost equilateral, consisting of three stars, Alpha and Beta of the second magnitude, and Epsilon of the third. Almost in the centre of this triangle but nearer to Epsilon is a fainter star Nu, of the fourth magnitude. Between Alpha and Beta and slightly above the line joining them is Kappa, also of the fourth magnitude.

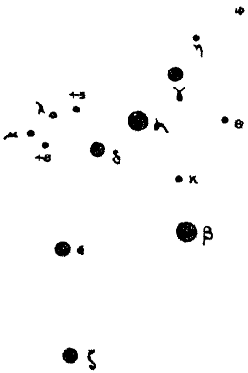

FIG. 5.—Perseus.

Alpha Persei is the brightest orb in a stream of stars, which forms the second distinguishing feature of the constellation. In order, and beginning from the highest point of the stream, the stars are Eta, of the fourth magnitude, Gamma, of the third, Alpha of the second, Psi of the fifth, Delta of the third. Here the stream curves sharply round, the stars in the curve being 48 Persei, Mu and Lambda of the

fourth magnitude, and 43 Persei of the fifth. The only other notable star in the constellation is Zeta, of the third magnitude, a somewhat isolated star, considerably below Epsilon.

There are three chief objects of interest in the constellation Perseus to the ordinary observer with the unaided eye or binocular. These are Beta Persei or Algol, the famous variable; the region surrounding Alpha Persei, or Mirfak; and the double cluster near to the star Chi Persei.

The name "Algol" is Arabic for "the demon"; and from this some astronomers have assumed that the old Arab astronomers were acquainted with the variations in its light. Be this as it may, the fact that the star is variable was not discovered until comparatively modern times, although the variations are quite easy to follow with the unaided eye. Probably the reason of this is that the normal appearance of Algol is that of an ordinary star of the second magnitude. As Mr. J. E. Gore remarks: "Shining with a steady light for about 59 hours its lustre suddenly begins to diminish, and in about 4½ hours its brilliancy is reduced to about one-third of its normal brightness. It remains at its faintest for about 15 minutes, and then in about 5½ hours recovers its former lustre." The variability of the star was discovered in 1669

by Montanari, an Italian, and again in 1782 by Goodricke, a young English astronomer, who accurately determined the period, which is 2 days, 20 hours, 45 minutes, 55 seconds. Goodricke was the first to suggest that the loss of light was due to partial eclipse of Algol by a large satellite, dark, or almost dark. This theory was confirmed twenty years ago by the late Professor Vogel of Potsdam, by means of what is known as Doppler's principle in spectroscopic observations. Vogel applied the principle to the observation of Algol, and he found that before each eclipse Algol was retreating from the Solar System, while after each eclipse it showed signs of approach. This proved conclusively that both Algol and its invisible companion-star were in revolution round their common centre of gravity, and that Algol was not inherently a variable, but merely a double star. Vogel also ascertained that in all probability Algol is a star about one million miles in diameter, and the satellite star about eight hundred thousand miles—about equal in size to our sun—the distance between the centres of the two stars being about three millions of miles. The presence of a third member of this remarkable system has often been suspected, although not yet confirmed. To the unaided eye Algol appears only a very ordinary star, with no outstanding

features; and it is remarkable that it was an amateur who discovered its variations, determined its period, and put forward the true theory of its variations.

Alpha Persei or Mirfak is the centre of a remarkable region of the heavens. When we observe this region with the binocular, we cannot but be impressed with its magnificence. There is a festoon of stars round Mirfak, arranged so symmetrically as to preclude the idea of a chance scattering.

Above Eta and near to the borders of Cassiopeia is the star Chi Persei. Near to this star is the magnificent double cluster in Perseus. It is visible to the unaided eye as a hazy spot of misty light. A field-glass shows it much more plainly; and even in a small telescope it is a striking spectacle, while in a large instrument it is awe-inspiring.

Perseus is notable in astronomical history as the constellation in which the famous temporary star of 1901—"the new star of the new century"—appeared. This star was discovered by the Rev. Dr. Anderson of Edinburgh in February 1901. At its maximum it surpassed Capella in brilliance, and indeed it was one of the most brilliant temporary stars ever recorded.

We have briefly surveyed the chief con-

stellations visible in the winter skies and have noted their chief stars and the most interesting binocular fields. Taking Orion as a starting point, the beginner is enabled to identify the other groups. After all the others have been identified, Orion still remains the chief attraction. As a recent American writer has remarked: "I have never beheld the first indications of the rising of Orion without a peculiar feeling of awakened expectation like that of one who sees the curtain rise upon a drama of absorbing interest. And certainly the magnificent company of the winter constellations of which Orion is the chief make their entrance upon the scene in a manner that may be described as almost dramatic." It must not be forgotten that, although the winter stars may be seen and identified in and near to cities, they are seen under their most favourable conditions in the country districts where the air is clear and pure. As the same writer has expressed it: "In the pure frosty air the stars seem splintered and multiplied indefinitely, and the brighter ones shine with a splendour of light and colour unknown to the denizen of the smoky city whose eyes are dulled and blinded by the blaze of street lights. There one may detect the delicate shade of green that links in the imperial blaze of Sirius, the beautiful rose-red light of Aldebaran, the

rich orange hue of Betelgeux, the blue-white radiance of Rigel, and the pearly lustre of Capella."

CHAPTER IV.

THE STARS OF SPRING.

To the lover of nature the early spring is always a time of joy and hope; to the lover of nature who is also a lover of celestial scenery, this feeling is tempered by one of regret that the brilliant constellations of the winter-time have disappeared from view, for this is the season described by Tennyson as the time

> "When the shining daffodil dies and the charioteer
> And starry Gemini hang like glorious crowns
> O'er Orion's grave low down in the west."

Leo.—The stars of spring seem very faint in comparison with their predecessors of winter. Not only are the stars of spring less brilliant; they are also more sparsely scattered. To the observer who is anxious to become familiar with the constellations visible at this time there is one great drawback: there is not among the spring star-groups a constellation so brilliant and notable as Orion among those of winter. There is, however, a group which is not readily mistaken and whose outline is

easily kept in mind. This is *Leo*—the Lion—the fifth of the constellations of the Zodiac.

Leo may be easily found by means of the stars of the Plough. A line drawn from Alpha Ursae Majoris—one of the "pointers"—through Lambda and Mu Ursae Majoris, directs the observer to the stars of Leo. Perhaps, however, the constellation may be recognised without this aid. Even the most

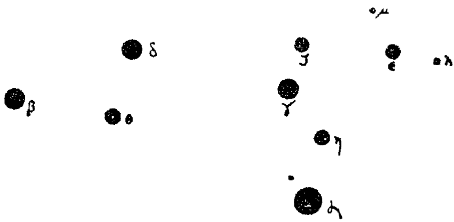

FIG. 6.—LEO.

casual star-gazer, casting a glance upward on any evening of spring, can hardly fail to notice a striking group of stars, east of the meridian, west of the meridian, or on the meridian itself, according to the hour of the night or the earliness or lateness of the season. The constellation consists of two parts—on the right-hand side a curve of stars known as "the sickle" from its resemblance to the implement of that name, and on the left-hand side a group of stars in the form of a triangle.

Between the two parts of the constellation there is a gap, filled by faint stars.

There are six principal stars in "the sickle"; and the star at the bottom at once attracts attention. It is Regulus or Alpha Leonis, one of the fainter stars of the first magnitude. The position of the Sun at the summer solstice was in this group when the zodiacal constellations were first arranged, and this gave to Leo and its chief star a primacy not warranted by the actual importance of constellation or star. Mr. Maunder has shown this very clearly in his discussion of Leo in *Astronomy without a Telescope*: "Our present name for the star," he says, "is the variant proposed by Copernicus, for the older Latin Rex. Ptolemy calls it 'Basilikus,' the Arabs give it 'Malikiyy,' 'the kingly' star, and the cuneiform inscriptions of the Euphratean valley refer to it as the 'star of the king,' whilst in ancient Persia it was the chief of the four royal stars. It is its place, however, and not its brilliance which has gained for Regulus this distinction, for almost all the first magnitude stars are its superiors in brilliance."

The next star of the curve is Eta Leonis, of the third magnitude. Above Eta, next in the curve, is Gamma, of the second magnitude. It is a double star visible in the telescope, and a favourite object for double-star observers.

The next star in the line is Zeta, of the third magnitude. At the summit of the curve—the handle of the sickle—is Mu, of the fourth magnitude; while below Mu is Epsilon, of the third. In a line with Epsilon to the right-hand side is a fifth magnitude star, Lambda Leonis.

A little south-west of Zeta is a point in the heavens, unmarked by any bright star, which has attracted the attention of astronomers for many years. There is a famous shower of meteors or falling stars known as the November meteors. It was discovered early in the last century that this shower was an annual one, generally unnoticed by the casual observer, but that every thirty-three or thirty-four years it became a magnificent spectacle. The paths of the meteors, traced backwards in the sky, were found to converge at the point near Zeta Leonis mentioned above. Hence the meteors were named "the Leonids." The shower is much less notable now than in former years, but November never passes without the appearance of a few meteors radiating from Leo. It is unnecessary to point out that the shower is caused by the Earth ploughing its way through the shoal of minute bodies known as meteors, and that the meteors merely appear to come from a point which lies in the same line of sight as the constellation Leo.

Between the Sickle on the right-hand side of the constellation and the triangle on the left-hand side there is a dearth of bright stars. On the left hand of the figure we notice the three stars, Delta, Theta and Beta, which form a right-angled triangle, of which Theta marks the right angle. Beta is of the second magnitude and is often spoken of by its Arabic name "Denebola." Theta is of the third magnitude and Delta of the second. Beta is an interesting object in a field-glass, as there are several fainter stars surrounding it.

Virgo.—Next to Leo, *Virgo*—the Virgin—is the most prominent constellation visible in spring-time. Virgo is the large star-group to the left-hand side of Leo and lower in the sky. It is easily identified, its figure resembling a large capital Y lying on its side. The stem of the Y is marked by two stars, Alpha Virginis—(Spica)—and Gamma. The latter star with Eta and Beta forms the right arm of the figure, and with Delta and Epsilon forms the left arm. The comparative brightness of the stars in Virgo and the dearth of other bright stars near renders the constellation very conspicuous.

Beginning at the foot of the Y, Spica or Alpha Virginis is the brightest star of the constellation. It is of the first magnitude and of a bluish-white colour. There is nothing

particularly remarkable about the appearance of Spica to the unaided eye, except its bright-ness. The remarkable fact concerning it is that it is a very close double star, so close as to be invisible in the telescope. By means of the spectroscope, however, we know that the bright star has a dark or nearly dark satellite star. The two stars, which are separated by only six and a half millions of miles, revolve

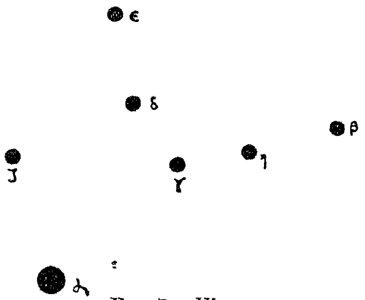

FIG. 7.—Virgo.

round their common centre of gravity in about four days, with a velocity of fifty-seven miles a second; and the joint mass of the two stars is two and a half times that of the sun. It is obvious that in this system we have an arrangement quite different from that in the Solar System. The equality in size of the two stars makes it impossible for the one to revolve round the other. Both revolve round their common centre of gravity.

Proceeding up the stem of the Y we reach Gamma Virginis, of the third magnitude. It is a famous double star, but of course far beyond the reach of the binocular. It may be seen with telescopes of 3 and 4 inches in aperture. The fainter star requires 185 years to complete its revolution. Here then we have a double star of exactly opposite type from Spica.

The four stars which, along with Gamma, form the two arms of the Y, are all of the third magnitude and do not call for particular attention. It is interesting to note that in the region of the sky between the arms of the Y and Beta Leonis, is the point known as the pole of the Galaxy. That is to say, this region of the heavens is farthest from the Milky Way. If we liken the starry sphere to an immense globe and the Galaxy to the equator of that globe, this particular region contains its northern pole. In this region of the sky the stars are most sparsely scattered.

Corvus and Crater.—The sky below Virgo and Leo is divided between two insignificant constellations—*Corvus*, the Crow, and *Crater*, the Cup.

Corvus may be recognised by the trapezium formed by its four chief stars, Delta at the north-eastern corner, Gamma at the north-western, Epsilon at the south-western, and

Beta at the south-eastern. Delta, Gamma, Beta and Epsilon are of about the third magnitude. Near to Delta is Eta, of the fifth magnitude; and below Epsilon is Alpha, of the fourth magnitude. Crater is a less notable group. The only noticeable stars are Delta of the third magnitude, Gamma of the fourth, and Alpha of the fourth. These three stars form a triangle.

Hydra and Cancer.—On the south and west of these constellations is the long straggling group known as *Hydra*, the longest constellation in the heavens, and one of the most difficult to identify. Its most brilliant star is Alpha Hydrae, known by its Arabic name of "Al Fard"—the "solitary"—the name possibly being suggested by the barrenness of the adjacent portions of the sky. Al Fard is a reddish star of the second magnitude and from its colour was named by the ancient Chinese astronomers "the red bird." Al Fard is really the only notable star in Hydra, which winds from the borders of Libra to the borders of *Cancer*. This notable though faint constellation may easily be found by means of the most northern stars of Hydra. These stars marking the head of the monster are above Al Fard, on the right-hand side. Directly above these stars and between Gemini and Leo, is the little group of Cancer, the Crab.

Insignificant though Cancer appears, it is the fourth of the zodiacal constellations. The stars Gamma, Delta, Zeta and Mu form a quadrilateral; while Delta and Mu, the two lowest stars of the quadrilateral, form a trapezium with Alpha and Beta. The most notable feature in the constellation is, however, the cluster "Praesepe," or the "Bee-Hive." This is visible to the unaided eye as a hazy cloud-like object between the two fourth-magnitude stars Gamma and Delta Cancri. Next to the Pleiades, this is the most conspicuous star-cluster in the heavens. It was noted by the ancient astronomers, who, however, failed to detect the individual stars and classified it as a "nebula" or little cloud—this being the first occasion on which this term was applied to a celestial object. Praesepe is a striking object in a binocular and in a small telescope, although much less noticeable than the Pleiades.

Two other insignificant groups may be noted among the spring constellations. Above Virgo and on the left-hand side of Leo is the constellation of *Coma Berenices*, which although not one of the original constellations—named in prehistoric times—is yet very ancient. The name signifies the "hair of Berenice," Queen of Egypt. This princess—the story goes—vowed her hair to the gods if her husband returned safely from a war in which he was engaged.

Her hair was stolen from the temple in which it had been placed after her husband's return, whereupon the royal astronomer of the day declared it had been translated to the celestial regions, and pointed to the shimmering star-group as proof of the truth of his assertion The constellation, while destitute of bright stars, possesses a number of faint ones and is an interesting field for the binocular.

Above Leo and Virgo and below the Plough is another insignificant constellation, *Canes Venatici*, the "Hunting Dogs." This constellation, indeed, is almost circumpolar, but is at its best position for observation in spring. There is only one bright star, designated Alpha, which is easily found when the Plough is known ; for it is the next bright star to Eta Ursae Majoris, the last star of the handle of the Plough. It is also known by the somewhat ludicrous name of Cor Caroli, "Charles's Heart." It was so named because it was believed by the Royalists to have shone with exceptional brilliance on the evening before Charles II. made his entry into London for the first time after the Restoration. There are no other bright stars in the constellation. To the telescopic astronomer it is chiefly famous on account of the famous spiral nebula. This magnificent object, however, is far beyond the reach of the unaided eye or binocular.

The constellations Bootes and Corona Borealis are by some astronomers included among the stars of spring ; but it is more correct to include them among the summer stars. They are certainly visible in spring-time, but they are most prominent of all in the short summer nights. Therefore in this work they will be described among the summer stars—in the next chapter.

The average observer of the heavens cannot fail to be impressed with the scarcity of bright stars in spring-time. In the winter skies, described in the last chapter, no less than seven stars of the first magnitude are visible—Sirius, Betelgeux, Rigel, Procyon, Aldebaran, Capella and Pollux, along with a large number of bright stars of the second magnitude. On the other hand, Regulus and Spica are the only first-magnitude stars among the spring constellations proper Not only are there few bright stars in spring, but as compared with other seasons of the year there is a remarkable dearth of stars of all magnitudes. The reason of this is not far to seek, and although its consideration leads into the higher problems of astronomy, it may be mentioned here.

As was seen in a previous chapter, the Milky Way or Galaxy is the ground-plan of the Universe. It is itself an agglomeration of

many millions of stars, individually invisible to the unaided eye, which are seen collectively as a belt of misty light. Not only is the Galaxy an agglomeration of faint stars, but it is a region of the heavens in which the bright stars are most thickly scattered. The late Mr. Gore, one of the ablest of non-professional astronomers, examined the positions of all the bright stars on the northern hemisphere. He found that, of thirty-two stars brighter than the second magnitude twelve lie on the Milky Way or on faint nebulous light connected with it; and of those brighter than the third magnitude thirty-three stars out of ninety-nine lie on the Galaxy. Thus, the number of brighter stars is considerably more than that due to the area of the Galaxy. In summer, autumn, and winter, we see the Milky Way more favourably than in spring. At this season of the year the part of the heavens exposed chiefly to our view is the region near to and round about the pole of the Galaxy. The stars increase in density from the pole of the Galaxy to the Galaxy itself; therefore the region round about Leo, Virgo, and Hydra is naturally the least rich region of the heavens.

This is the explanation of the relative paucity of stars in the skies of spring. In summer, although owing to the length of day-

light we see less of the starry heavens than in spring, richer and more crowded regions come into view. These will be considered in the next chapter.

CHAPTER V.

THE STARS OF SUMMER.

"IN the soft air of a summer night," says an American astronomer, "when fireflies are flashing their lanterns over the fields, the stars do not sparkle and blaze like those that pierce the frosty skies of winter. The light of Sirius, Aldebaran, Rigel and other midwinter brilliants, possesses a certain gem-like hardness and cutting quality, but Antares and Vega, the great summer stars, and Arcturus, when he hangs westering in a July night, exhibit a milder radiance, harmonising with the character of the season." This description is true to nature: the light of the summer stars is different from those of winter, but the difference is chiefly atmospheric; there is no peculiar quality in the light of the various stars which are visible in summer-time.

The chief drawback to the study of the constellations in summer is the fact that the period of actual darkness is so brief. The summer stars, in short, are not so obvious as

those of winter. They do not intrude themselves on the view of the observer; it is necessary for him to look for them. They are none the less interesting on this account; there is indeed a certain charm in watching the summer sky darkening as midnight approaches and the shy stars peeping out one by one in the heavens. But the student of the summer skies must be enthusiastic. His interest in the heavens must be first stimulated by observation of the constellations which dominate the skies of winter and spring respectively.

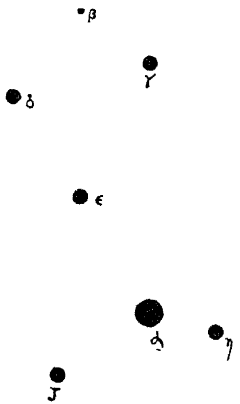

FIG. 8.—Bootes.

Bootes.—The chief constellation of the summer skies is identified by its principal star, Arcturus. This star is very easily recognised. A line drawn from Eta Ursae Majoris, the last star in the handle of the Plough, will reach Arcturus. This is one method of finding the star; but Arcturus is so obvious that it will attract the attention of the most casual observer. But for the presence of this brilliant star the constellation *Bootes* would be in no way remarkable. At the top of the constellation

is a triangle formed by three stars—Beta, Gamma and Delta. Delta, at the left-hand corner of the triangle, is almost in a straight line with Epsilon Bootis and Arcturus ; while Arcturus itself forms a triangle with other two fainter stars Eta and Zeta. The figure of Bootes is one not easily remembered, and although the method of remembering the stars by means of lines and triangles has, speaking generally, many drawbacks, in the case of Bootes it is the only method practicable.

Arcturus, or Alpha Bootis, is one of the most brilliant stars in the heavens. The majority of astronomers consider Arcturus to be slightly more brilliant than Vega and Capella ; but there is not unanimity on this point, for the three stars are of different colours, Vega being bluish-white, Capella bright yellow, and Arcturus a deeper yellow, shading into orange. It is therefore difficult to determine the minute differences in magnitude ; yet the majority of astronomers believe Arcturus to be the brightest of the three. It is therefore the most brilliant star north of the celestial equator, and with the exception of Sirius, the brightest star visible to observers in the northern hemisphere.

Arcturus, which is situated at an enormous distance from the Solar System, appears to be a star of gigantic size. Dr. Elkin, an American

astronomer, made an attempt to measure the distance of Arcturus. He found that the star's displacement, due to the change in the observer's position, when he is at exactly opposite points of the Earth's orbit—in January and July respectively, for instance—is about equal to the apparent distance between the heads of two pins placed an inch apart and viewed from a distance of about 180 miles. The distance deduced from Dr. Elkin's measurement is of course by no means beyond doubt; but assuming that the estimate is fairly near the truth, Mr. Garret P. Serviss, an American astronomer, has calculated that if the Earth were situated midway between the Sun and Arcturus it would receive over 5000 times as much light from the star as from the Sun; and assuming that the radiation of the star is the same per unit of surface as the Sun, he finds that Arcturus exceeds the Sun in volume by about 375,000 times.

Of the other bright stars in the constellation, Epsilon is of the second magnitude, Eta, Zeta, Gamma and Delta of the third, and Beta and Mu of the fourth.

Mr. Maunder compares Bootes to Orion, remarking that when Arcturus is excluded, "the principal remaining stars of the constellation make up a representation, pale and distorted, it is true, but a representation for all

that of the most glorious constellation in the sky." This idea may assist the observer in tracing the shape of Bootes.

Corona Borealis.—To the left of Bootes is a constellation which although small is very conspicuous—*Corona Borealis*, or the Northern Crown. The group is shaped exactly like a coronet, and, as it really resembles the object after which it is named, it is easily identified and as easily remembered. There are six chief stars in the constellation. Beginning at the right-hand side, the stars are in order—Theta, Beta, Alpha, Gamma, Delta and Epsilon. Alpha is of the second magnitude and the others of the fourth.

In this constellation, in 1866, appeared the famous temporary star known as "the blaze star." It was discovered by an Irish amateur astronomer who, on casting a glance round the skies, saw the familiar configuration of Corona Borealis completely altered by the presence of a brilliant stranger. Four hours earlier it was not visible; in a few hours some mighty conflagration had taken place, which caused the star to shine with at least nine times its former brilliancy; for it is believed that it was known as a minute telescopic object before the outburst.

East of Bootes and Corona Borealis is a region of the heavens which is probably one

of the most difficult for the observer to know thoroughly. As our glance travels eastward along the heavens we reach richer regions where the stars are more profusely scattered; for we are again approaching the vicinity of the Milky Way, one of the branches of which passes through Ophiuchus and Serpens. The stars are not grouped in easily remembered figures, nor are the constellations themselves marked off one from the other. Serpens and Ophiuchus, for instance, intersect in a manner which is very puzzling to the beginner in constellation study. The key to this intersection is found in the names of the star-groups themselves. "Serpens" is Latin for "the Serpent" while "Ophiuchus" is "the Serpent-bearer." On the old globes in which the mythical figures are represented, Ophiuchus the serpent-bearer is represented as engaged in a life-and-death struggle with the serpent which is coiled round him. The natural grouping of the stars has in this case been ignored for the purpose of representing the old fable in the sky, with the result that it is very difficult for the beginner to recognise which stars belong to Serpens and which to Ophiuchus. Above these two groups is Hercules, which, although not a striking constellation, is much easier to follow.

Hercules.—On the left of Corona Borealis

and somewhat higher in the sky than that constellation, our attention is attracted by four stars which form a quadrilateral which is almost a square. These four stars are Pi of *Hercules*, on the top left-hand corner, Eta on the top right-hand corner, Zeta on the bottom right-hand, and Epsilon on the bottom left-hand. All four are of the third magnitude. Close to Pi is Rho, of the fourth magnitude, while on a straight line from Eta to Zeta, but considerably nearer to the former star, is the famous star-cluster in Hercules. This wonderful celestial spectacle is beyond the reach of the unaided eye, but it may be noticed if looked for with the binocular and seen fairly well with a small telescope. Larger instruments have shown it to be one of the most wonderful objects in the entire heavens—containing many thousands of stars. For many years it was believed that the cluster represented a mere local aggregation of stars, but our whole conception of its place in the Universe has been revolutionised by a remarkable investigation carried through within the last few years by a distinguished American astronomer, Dr. Harlow Shapley. From an exhaustive study of the colours and absolute magnitudes of the stars in the cluster Dr. Shapley reached the conclusion that it is situated at a distance so great that light requires 100,000 years to

travel from the cluster to our system, and 1100 years to cross from one side of the cluster to the other. In fact, the cluster is possibly an "island universe," though considerably smaller in extent and perhaps not altogether independent of our Galaxy. That it is analogous in its nature is shown by the recent work of Dr. Shapley, who has detected the presence of a zone of galactic concentration in the cluster, similiar to the Milky Way. Professor Eddington has truly remarked that "were we transplanted into the midst of the great Hercules cluster our knowledge of its constitution could scarcely be so precise as that which Mr. Shapley has discovered at a distance of 100,000 light years; and the labour would have been incomparably greater."

Thus when we observe the cluster it is well to realise that we are looking far beyond the limits of the Stellar System into vistas of infinity.

From the quadrilateral in Hercules the other stars of the constellation may be found. Almost directly below Zeta is Beta, of the second magnitude, the space between Zeta and Beta being a little greater than that between Zeta and Eta. Close to Beta, but slightly lower in the sky, is Gamma, between the third and the fourth magnitude. To the left of the quadrilateral is a portion of the heavens in which it seems at first very difficult

to discern any order in the scattered stars. There is, however, a curve of stars which may be remembered. Beginning with Beta after a considerable space we come to Delta, of the third magnitude. As far from Lambda as Lambda is from Delta, we come to Mu, of the third magnitude. The curve turns more sharply, and we reach Xi and Nu, two fourth-magnitude stars comparatively close together. Again there is a considerable gap and we reach Theta, also of the fourth magnitude, which is almost in a straight line with three stars—so that the curve becomes practically straight. These are a fifth-magnitude star marked 90 Herculis, Iota of the third magnitude, and Beta Draconis of equal brightness. In fact Iota Herculis is naturally one of the four stars forming the notable diamond-shaped figure in Draco—the other three being Xi, Beta and Gamma Draconis.

Ophiuchus and Serpens.—Alpha Herculis, a bright reddish star, irregularly variable, may be found almost directly below Delta—a considerable stretch of sky intervening. Close to this star is Alpha Ophiuchi. So close indeed are the two stars that Alpha Herculis seems to belong more naturally to *Ophiuchus* than to Hercules. Below Alpha Ophiuchi, a second-magnitude star, is Beta of the third magnitude ; and again below this star, although not in a

straight line but in a line slanting to the left, is Gamma, of the third magnitude. We may note that in this constellation appeared the famous new star of 1604. In this same group, too, is situated a faint star with a very large "proper motion," discovered by Professor Barnard of the Yerkes Observatory in 1916. This faint star is situated at a distance which light requires a little over six years to traverse. It is with the single exception of Alpha Centauri our nearest known stellar neighbour. Obviously, it must be one of the smallest and faintest of the stars.

We may now direct our attention to *Serpens*, which begins below Corona Borealis in the space between Hercules and Bootes. A winding stream of stars may be traced from near the boundaries of Hercules—Kappa Serpentis of the fourth magnitude, Beta of the third, Delta of the third, Alpha of the second (near to which is Lambda of the fourth), Epsilon of the third, and—after a considerable gap—Delta, Epsilon and Zeta of Ophiuchus. It is almost impossible to remember these stars from any figure or grouping. They must be followed star by star, and it is fortunate for the observer that they generally run in lines and streams. There are some magnificent binocular fields in Serpens, which is well worthy of careful attention.

Lower down in the heavens are the three least-known constellations visible to northern observers—Libra, Scorpio and Sagittarius. These, which are zodiacal constellations, only rise a short distance above the horizon; and as their period of visibility is in summer-time, when the evenings are so long clear and the period of darkness is brief, these star-groups are among the least known in the heavens.

Libra.—*Libra*, or the Scales, the seventh constellation of the Zodiac, lies east of Virgo and considerably lower in the heavens. Alpha, Delta and Beta form a triangle. Alpha is almost exactly on the ecliptic, the line which marks the Sun's apparent path in the heavens. In the field-glass this star is a beautiful double. Beta is of a greenish hue. This star is believed to have decreased in magnitude within the last two thousand years. It is now of the second magnitude; whereas Ptolemy catalogued it as a star of the first magnitude.

Scorpio.—Next to Libra, but more conspicuous although lower in the sky, is *Scorpio*—the Scorpion—the eighth constellation of the Zodiac, or rather the part of Scorpio which is visible to observers in our northern latitudes. In more southern latitudes Scorpio is one of the most magnificient constellations in the heavens; it is not only rich in stars but it is immersed in one of the most brilliant portions

of the Milky Way. The star Xi of Scorpio, which is on a line with Mu Serpentis, is the first of the curve of stars which distinguish the northern portion of the star-group. Below Xi lies Nu, and from Nu the curve includes Beta, Delta, Sigma, Alpha and Tau. Alpha, better known by its Greek name of Antares, is a star

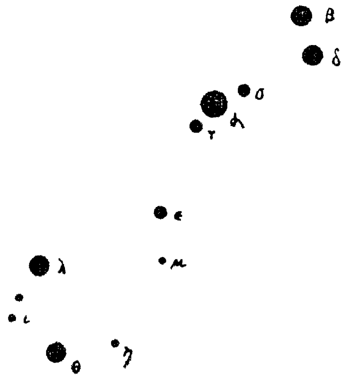

FIG. 9.—Scorpio.

of the first magnitude. It is of a fiery red colour, hence its name of "Ant-Ares," the rival of Ares or Mars. It is a star of the same spectral type as Betelgeux in Orion. When observed with a good telescope it is seen to be a double star, the little satellite-orb being of a greenish colour. For many years these colours —red and green—were thought to be the effect

of contrast, but the spectroscope has shown that the colours are real.

The constellation is full of interesting and beautiful fields even for an opera-glass ; and if Scorpio were seen in winter, spring or autumn, it would probably be one of the most familiar and most thoroughly explored of star-groups ; but its slight elevation above the horizon and the fact that it is only seen in the summer months render it less interesting to the beginner than its brilliance and importance warrants.

Sagittarius.—The ninth constellation of the Zodiac, *Sagittarius* the Archer, lies to the left-hand side of Scorpio, but slightly higher in the heavens. Although more elevated, however, it is less brilliant than Scorpio and possibly less familiar ; while it is certainly less easy to follow. It is chiefly notable for the presence of the Milky Way, which is here very brilliant ; and in the evenings of late summer, this part of the Galaxy, low down in the south-west, shines with a strange brilliance. The chief stars of Sagittarius visible to northern observers—included in a curve which begins near the borders of Ophiuchus—are Mu, Lambda, Delta and Epsilon, the three latter being set in the stream of the Milky Way. In the southern parts of Sagittarius the Milky Way divides into two branches, one branch running into Scorpio and Ophiuchus and the

other running straight through Sagittarius into Aquila.

Lyra.—This star-group cannot be mistaken. It lies to the left of Hercules and to the right of the stream of the Galaxy. Its most distinguishing feature is its brightest star, Vega or Alpha Lyrae. In the chapter on the northern stars, reference has been made to Vega, which like Capella is a circumpolar star, and which occupies the position in summer which Capella holds in winter, being high in the sky. Vega, whose light is of a bluish-white tinge, is one of the most brilliant stars in the sky. It appears to be situated at an immense distance from the Solar System, and to be a star of about three or four times the light-giving power of Sirius, which considerably outshines our Sun.

The configuration of Lyra is easily remembered. On the left of Vega are three stars of the fourth magnitude, Epsilon, Zeta and Delta, and two of these, Epsilon and Zeta, form with Vega an equilateral triangle. Below Vega are Beta and Gamma Lyrae, both of the third magnitude, which form a quadrilateral with Delta and Zeta. These are the chief stars of the constellation.

Of these stars Beta is notable as a famous variable star, the variations of which are easily within reach of the unaided eye. It varies

from the third to the fourth magnitude in 12 days 21 hours 47 minutes. The variations of this star are believed to be due to the revolution of two stars, one less brilliant than the other round their common centre of gravity. The stars, according to Newcomb, are of unequal size and almost in contact, and the smaller body is much brighter than the larger. The system thus revealed is certainly one of the most remarkable in the heavens. This variable star is a very suitable object for the observer who is commencing the study of variables, as its changes can all be followed by the unaided eye.

Epsilon Lyrae is a double star, visible as such to keen eyesight. The binocular easily reveals the star as double, and a small telescope shows each of the two to be itself double: so in Epsilon Lyrae we have a quadruple star. Perhaps, however, the most interesting star in the constellation is Delta Lyrae, not on account of the star itself, but on account of a point in the sky near it. The most reliable astronomical calculations have shown that the Sun, carrying with it the Earth and the planets, is travelling towards this portion of the heavens with a velocity of about eleven miles per second. As Sir Robert Ball has remarked: "The speed with which this motion of our system is urged is such as to bring us every

day about 700,000 miles nearer to this part of the sky. As you look at Delta Lyrae to-night, you may reflect that within the last twenty-four hours you have travelled towards it through a distance of nearly three-quarters of a million of miles. So great are the stellar distances that a period of not less than 180,000 years would be required before our system, even moving at this impetuous speed, could traverse a distance equal to that by which we are separated from the nearest of the stars." The observer may be tempted to ask, when then shall we reach Delta Lyrae? In all probability we shall never reach it. For the star, like our own Sun, probably has its own motion, and even when our system in the course of thousands of thousands of years—if it is then in existence—does reach the place now occupied by Delta Lyrae, that star will be far away from its present position. As we contemplate the region of the heavens towards which we are moving, surrounding this little star, great thoughts of our world and its destiny arise in our minds.

Some astronomers regard Cygnus and Aquila, the adjacent star-groups, as summer constellations; but we shall consider them as autumn groups, because, although well seen in summer, they are seen in their full glory in the autumn season.

CHAPTER VI.

THE STARS OF AUTUMN.

In the calm clear skies of autumn the most notable feature on a moonless night is the majestic sweep of the Galaxy spanning the heavens like a great arch. In September and October the Milky Way is seen to its fullest advantage; and in its course in this part of the heavens it passes through some of the most wonderful regions of the sky. At this season of the year it is easier to comprehend the true nature of the Milky Way than at others. As was mentioned previously, it is the ground-plan or equator of the entire Universe of stars; the stars are there much more numerous than in other portions of the heavens. A number of observations with a telescope or even with a binocular is sufficient to show that this crowding of the stars towards the Galaxy is a fact. In a telescopic or binocular field, in this very region the observer may count as many as fifty or sixty stars; while in an equal field in Virgo or on any part of the heavens, near to the galactic poles, he may count as few as five or six. The Galaxy is the fundamental reference plane of the entire Universe, just as the equator is of the Earth. In

this chapter we shall discuss the constellations of autumn, beginning with those on the Galaxy.

Cygnus.—Looking up to the heavens on an autumn evening, and glancing along the Galaxy, it is impossible to overlook what is, if not the most brilliant, perhaps the most interesting constellation in the entire heavens. *Cygnus*, the Swan, is immersed in one of the most brilliant parts of the Milky Way. It is situated to the left of Lyra, but it is so conspicuous that no directions are required to find it. The constellation is shaped like a cross; indeed so obvious is the cruciform shape that it has often been termed the "Northern Cross." At the centre of the cross is the star Gamma. The horizontal arm of the cross is marked by Epsilon, Gamma and Delta, beginning at the left-hand side. The perpendicular arm is marked by Alpha, Gamma, Eta and Beta, beginning with the uppermost star, almost in a straight line. In addition there is another bright star, Zeta, not included in the cruciform figure.

Of all constellations Cygnus includes the greatest variety of notable stars from the point of view of the observer with the unaided eye or binocular. Beginning with Gamma, the central star of the constellation, of the second magnitude, it is to be noted that it is the

central star of a very wonderful region, being itself the last star of a curve or crown of stars. Alpha Cygni, also known by its Arabic name of Deneb, is one of the faintest stars of the first magnitude ; and the region surrounding this star is even more striking than that round Gamma Cygni. The star is thickly immersed in the Galaxy and well repays observation with the binocular. The boundary

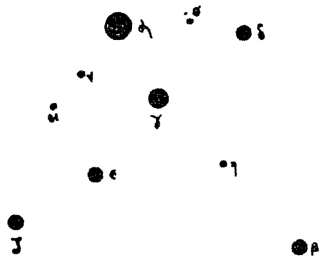

FIG. 10.—Cygnus.

between the galactic light and the darkness of the small rift in the Milky Way near the star is marked by a stream or line of stars which appears distinctly connected with the nebulous light of the Milky Way.

With the aid of the binocular it is easy to find 61 Cygni, the second nearest star in the northern hemisphere. In a straight line from Alpha Cygni, parallel to the horizontal arm of the cross, we reach Nu, a star of the fourth

magnitude. Prolonging the line not quite so far as the distance from Alpha to Nu, we reach a faint star of the fifth magnitude. This is the famous 61 Cygni, one of the nearest stars in the heavens. This star is distant from the Solar System 459,000 times the distance of the Earth from the Sun. Light requires about seven years to reach the Earth from this star, which is thus much nearer to the Solar System than any of the most brilliant stars in the northern sky. Relatively to the Sun, it is a very small star.

To the naked-eye observer, the brilliance of the Galaxy in Cygnus is very noticeable. There is a luminous spot north of Alpha, and between Beta and Gamma the galactic light is very brilliant. Perhaps, however, the most remarkable object in the constellation is the star Beta, of the third magnitude. A field-glass, or better still a small telescope, shows the star to be double, the large star, of the third magnitude, being topaz yellow and the smaller one sapphire blue. A view of this star is a never-to-be-forgotten spectacle.

At the risk of a digression we may turn our attention briefly to the coloured stars, such as Beta Cygni, and to the conditions existing on planets revolving round any of these stars. Proctor, in one of his books, discussed the scene visible from any planets situated

thus. He supposed one of the stars to be blue and the other orange—as is practically the case with Beta Cygni—and the planet to be placed in the same position as the Earth in our system. There would be an endless variety of sights in the heavens. The blue and orange suns might rise together and produce "double day," or the blue sun might rise as the orange sun was setting and there would be no night. The clouds would present extraordinary appearances, some parts shining blue, some parts orange, according to whichever sun happened to shine direct upon them. The case is of course hypothetical. It must be borne in mind that such systems must be completely different from the solar family. In our system we have one bright star holding sway over a number of planets. In these systems there are two suns, which may or may not have planets revolving round them. If such planets do exist, and there is no reason why they should not, they will certainly experience very varied sights in their skies.

Aquila.—Proceeding downwards along the stream of the Galaxy we come to the constellation *Aquila*, the Eagle. This constellation is easily recognised by its three chief stars Gamma, Alpha and Beta, close together and almost in a straight line. The same line prolonged downwards reaches Theta. In a straight line

with Theta, pointing north-west, are other two stars, Eta and Delta. At the extreme north-western corner of the constellation are two stars Zeta and Epsilon ; and at the south-western extremity is Lambda.

Of the stars in Aquila, Alpha is of the first magnitude, Gamma, Theta, Delta and Zeta of the third ; Beta between the third and the fourth, and Epsilon and Lambda of the fourth. Eta is a variable star, varying from the third magnitude to the fourth in 7 days 4 hours.

Alpha Aquilae, better known by its Arabic name of Altair, stands midway between Beta and Gamma. It is a bright star of the first magnitude, of a bluish-white tint. It has been calculated that light requires about seventeen years to travel from Altair, and whether this calculation be correct or not, it is certainly nearer than many other stars of the first magnitude. The Galaxy is very bright in Aquila, although scarcely so striking as in Cygnus. Lambda stands on a bright spot of milky light, which is known as Scutum Sobieskii—"Sobieski's Shield."

On June 8, 1918, a brilliant temporary star blazed out in Aquila, close to the boundary of Serpens. At maximum it surpassed Nova Persei, and was the most brilliant "Nova" since 1604. By September its light had decreased to the fifth magnitude. As in the case

of Nova Persei, Nova Aquilae was observed independently by a number of observers.

Between Aquila and Cygnus are three insignificant little groups which scarcely deserve to be designated as constellations. Above the three stars, Gamma, Alpha and Beta is *Sagitta*, the Arrow, which contains no very remarkable objects and might well be included in Cygnus or Aquila. To the left and slightly lower in the heavens is *Delphinus*, the Dolphin, the most conspicuous of the three groups. It lies to the left of the Galaxy and is easily noted on a clear night. There are four stars arranged in the form of a trapezium, Alpha and Beta on the right, Gamma and Delta on the left. Beta is of the third magnitude and the other three of the fourth. Above Delphinus is *Vulpecula*, the Fox. It contains no notable stars, and is generally disregarded by astronomers.

Capricornus.—Below Aquila and to the left of Sagittarius is *Capricornus*, the Goat, the tenth of the zodiacal constellations. The chief stars of Capricornus, Alpha and Beta, may be easily found exactly below Altair, much lower down in the heavens. The sky is much more barren here than in Aquila, for the Galaxy slopes away into Sagittarius and Scorpio.

Alpha Capricorni, the uppermost of the two stars, is a double star, visible to the unaided eye, and well seen in a binocular. The two

stars have no connection, and merely appear close together because they are in the same line of vision. Beta is also a double star, as seen in the binocular. Both Alpha and Beta are stars of the third magnitude. Almost in a line with Beta are the stars Theta, Iota and Gamma of the fourth magnitude, and Delta of the third. They are not, however, in any way notable. On the whole Capricornus is not a particularly interesting constellation to the observer either with the unaided eye or the binocular.

Aquarius and Pisces.—A similar remark applies to *Aquarius* and *Pisces*, the eleventh and twelfth constellations of the Zodiac respectively. Aquarius fills a large part of the heavens, stretching from the boundaries of Aquila above Capricornus down to the horizon. Alpha Capricorni is almost in a straight line with Epsilon, Mu, Beta and Alpha Aquarii. Epsilon is of the fourth magnitude, Mu of the fifth, and Beta and Alpha of the third. Close to Alpha is a compact group of four stars, the most notable feature in the constellation—Gamma, Zeta, and Eta almost, but not quite, in a straight line, and Pi above Zeta. Gamma and Zeta are of the third magnitude, Eta of the fourth and Pi of the fifth. Below this group is a quadrilateral, consisting of Lambda, Theta, Iota, and Delta. On a clear autumn

evening a bright star is sometimes to be seen glimmering below Aquarius. This is Fomalhaut, of the first magnitude, the chief luminary of the southern constellation *Pisces Australis*, the Southern Fish. This star is only seen on evenings when the horizon is specially clear.

Pisces—the Fishes—the twelfth constellation of the Zodiac, is, like Aquarius, an uninteresting constellation with no bright stars, but it is easy to follow, owing to the symmetrical arrangement of its stars. The chief stars beginning at the borders of Aquarius are Beta, Gamma, Iota, Omega, 41 Piscium, Epsilon, Mu, Nu, Xi, and Alpha. Another stream runs upwards from Alpha, and includes Pi, Eta, Rho, Chi, and Upsilon, Eta, and Gamma, the brightest stars of the constellation, are of the fourth magnitude.

Cetus.—To the left of Aquarius and lower down in the heavens than Pisces is the large constellation *Cetus*, the Whale. The figure of Cetus is fairly easy to follow. Mr. Maunder compares it to that of a lounge chair. Alpha, Gamma, Delta, and Omicron mark the head-rest of the chair. Zeta and Tau, Theta, Eta, and Beta form the lower portion of the figure. Alpha and Beta are of the second magnitude, Gamma, Zeta, Tau, Theta, and Eta of the third, and Delta of the fourth. The most remarkable star in the constellation is Omicron,

generally known as "Mira Ceti"—the wonderful star of Cetus. It is one of the most remarkable of variable stars. Unlike Algol and the other variables which have been noted in previous chapters, Mira runs through its cycle of variations not in days, but in months. The period is not regular, like the short-period variable stars, but varies considerably. On the average it is about 331 days. The star has been under observation for three centuries, and has been followed through many cycles. It varies from the third to the ninth magnitude as a rule, but sometimes at maximum it is much more brilliant, and has been known to reach the first magnitude. The variations of Mira have never received any completely satisfactory explanation; they are certainly not due to eclipse, like Algol and Beta Lyrae. Probably they result from great internal disturbances.

Eridanus and Aries.—Between Cetus and Orion is *Eridanus*, the River, described in the chapter on the winter constellations. Above Cetus and to the left of Pisces and the right of Taurus is *Aries*, the Ram, the first of the zodiacal constellations. There are only three bright stars, Alpha, Beta, and Gamma, arranged in a neat little group, Beta and Gamma being close together. Alpha is of the second magnitude, Beta of the third, and Gamma of the

fourth. Gamma is a double star, the first discovered telescopically, in 1667; but it is beyond the reach of the binocular.

Pegasus.—Returning to Aquarius we recognise above that star-group a very noticeable constellation in a somewhat barren part of the sky—*Pegasus*, or the Winged Horse. The most notable feature about Pegasus is the so-called "Great Square of Pegasus," although strictly speaking the title is incorrect, for the

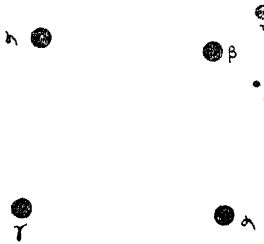

FIG. 11—Pegasus.

star at the top left-hand corner belongs to the neighbouring constellation Andromeda. It is impossible to fail to recognise Pegasus. The great square is one of the most notable configurations in the heavens, not only on account of the brightness of the stars forming it, but also because of the dearth of bright stars within the figure itself. All four stars of the square are of the second magnitude. Beta Pegasi is at the top right-hand corner, Alpha

at the bottom right-hand corner, and Gamma at the bottom left-hand corner.

Close to Beta are Mu, and Lambda, of the fourth magnitude. An irregular quadrilateral is formed by Alpha, Zeta, Theta, and Epsilon, all of which are easily identified.

Andromeda.—Although Pegasus is so noticeable a constellation, it is singularly barren in interesting stars or binocular fields. Of more interest is the neighbouring constellation *Andromeda*. As already mentioned, Alpha Andromedae is the star at the top left-hand corner of the great square.

Almost but not quite in a straight line with Alpha are Beta and Gamma Andromedae; all three are of the second magnitude. Between Alpha and Beta, but below the imaginary line joining them, are Delta of the third magnitude, and Epsilon of the fourth. Delta of the third and Epsilon of the fourth are almost in a straight line with Pi; perpendicular to the line joining Alpha, Beta, and Gamma, is a line which almost joins Mu, Nu, and Beta. The star Nu is only interesting on account of its proximity to one of the most famous objects in the heavens—the great nebula in Andromeda. This famous nebula is easily visible to a person of average eyesight, being faintly visible to the unaided eye. It is well seen in a binocular, and even in a small telescope it is a very

impressive spectacle. This nebula rivals the great nebula in Orion as a celestial spectacle; it has been closely studied by astronomers for many years, and since the application of photography to the heavens its study has proceeded with greater rapidity than ever. Formerly it was believed that the nebula was a cluster of stars, too distant for the individual stars to be separately visible. Later, the general view was that it was a true nebula, a mass of gas in a more condensed state than that in Orion. Recently, however, photographic and spectroscopic research seems to indicate that it lies beyond the Stellar System and may possibly be an external galaxy, too far away for the individual stars to be separately visible. But in this case there is not the same degree of certainty as in that of the cluster in Hercules.

In 1885 a temporary star appeared in the centre of the nebula. Other three have been detected in recent years.

Between Andromeda and Aries is the little constellation of *Triangulum*, the Triangle. The constellation, like Delphinus and Sagitta, contains no stars of importance. Beta Trianguli is of the third magnitude, and Alpha of the fourth.

Next to Andromeda, Triangulum, and Aries, and to the left of these groups we come to the

constellations of Perseus and Taurus, discussed in the chapter on the winter constellations. These fine groups come into prominence in the autumn, but it is in winter that they reach their most favourable position for observation.

CHAPTER VII.

THE SOUTHERN STARS.

A DISTINGUISHED writer on astronomy has remarked that "there is a strange unforgettable sensation in the first voyage from our high northern latitudes to the southern hemisphere. Besides the disappearance of old friends and the coming into sight of stranger stars, the known stars that still remain to us adopt most unfamiliar attitudes, and these become more and more perplexing the further south we go." In other words, a considerable number of the constellations visible in these latitudes are invisible in Australia, South Africa and South America, while the constellations which are visible here are seen inverted.

As was seen in the preceding chapters, a considerable number of stars visible in the northern hemisphere do not set. On every clear night we are able to see the Plough, Cassiopeia, the Pole Star and other notable

stars and constellations. A number of stars are visible to us in their different seasons, such as Orion, Leo, Virgo, and generally speaking, the constellations of the Zodiac; while a considerable number of star-groups are totally invisible to us in the north, because they do not rise above our horizon. These are the southern circumpolar stars. Seen from the southern hemisphere, these stars do not set; they occupy the same position to the inhabitants of the southern lands as the northern circumpolar stars do to us. To the dwellers in Australia, South Africa and South America, the Plough, Cassiopeia, and other northern star-groups are quite invisible; on the other hand, Orion, Pegasus and the constellations of the Zodiac are visible from both hemispheres.

The southern sky may be divided into two portions—a portion rich in stars and a portion poor in stars.

We may conveniently begin with *Scorpio*, a constellation which, as was noted in a previous chapter, is not seen to advantage in northern latitudes. In the south Scorpio is seen in its full magnificence high in the sky, almost exactly overhead. Following the course of the Galaxy—here very brilliant—we reach the constellations *Lupus*, or the Wolf, and *Ara*, the Altar. Lupus is a notable constellation, three of its stars being brighter than the third magnitude.

Following the course of the Galaxy we come to the three constellations, *Centaurus*, or the Centaur; *Crux*, or the Cross; and *Argo Navis*, or the Ship Argo. These are three very famous groups. Centaurus has ten stars brighter than the third magnitude. Alpha and Beta, immersed in the stream of the Milky Way, are of the first magnitude, Alpha being indeed one of the most brilliant stars in the sky, inferior only to Sirius and Canopus in brilliance.

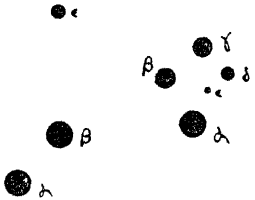

FIG. 12.—Centaurus and Southern Cross.

Alpha Centauri is interesting as the nearest of the stars. Its distance was measured in the years 1831–2 by Thomas Henderson, Astronomer-Royal at the Cape of Good Hope, and afterwards Professor of Astronomy in the University of Edinburgh and Astronomer-Royal for Scotland; and in point of fact it was the first star whose distance was successfully measured. It is distant about twenty-five billions of miles from the Solar System. It is also well known as a binary, or revolving

double star. Recently Mr. R. T. A. Innes, of Johannesburg, has discovered a minute star at about the same distance and probably connected with the system of Alpha Centauri. It is the faintest known star in the Universe, its luminosity being only one ten-thousandth that of the Sun.

Centaurus also contains other interesting objects, notably the magnificent cluster Omega Centauri.

The *Southern Cross* is a small constellation in area, but it is a brilliant group, containing three stars brighter than the second magnitude. It is thickly immersed in the stream of the Galaxy, and is perhaps rendered more noticeable by the wonderful gap in the Milky Way known as the "coal-sack." There is in the constellation Cygnus a rift in the Galaxy which has sometimes been named the "northern coal-sack," but the great gap in Crux has been described as truly an awe-inspiring object —a region in the midst of "clusters and beds of worlds," yet destitute of stars. Here we seem to get a glimpse through the visible Universe itself into that region which has been designated the "darkness behind the stars."

Leaving the Cross, the Galaxy passes into *Argo Navis*, a constellation so large that astronomers found it necessary many years ago to subdivide it into four smaller groups—

Malus, or the mast ; Vela, or the sails ; Puppis, or the stern, and Carina, or the keel. Argo contains fifteen stars brighter than the third magnitude, one of which is the well-known Canopus. This orb is, with the exception of Sirius, the brightest star in the sky, and its distance is so vast that it can only be estimated.

In this constellation too is situated Eta Argus, the famous "link" between variable and temporary stars. Originally an inconspicuous star, it was observed by Sir John Herschel in 1838 to blaze up to the first magnitude, when it equalled Aldebaran in brilliance. Five years later it equalled Canopus, and was one of the most brilliant stars in the sky. Since then the star has steadily decreased in magnitude, and now it is barely visible to the unaided eye.

After leaving Argo, the galactic stream passes into Canis Major, which is seen to greater advantage in the southern latitude than in the north ; this star-group, however, was described in an earlier chapter.

We have described the course of the Galaxy in the southern hemisphere ; in other words, the rich region. The remaining portion of the southern circumpolar heavens is very poor in stars. The south celestial pole is situated in the constellation *Octans*—a group very poor in stars, containing no orb as bright as the

fourth magnitude. The star nearest the southern pole is Sigma Octanis, of the sixth magnitude, just visible to the unaided eye ; so there is no south pole star in the true sense of the word. Round Octans are a number of star-groups equally inconspicuous—Pavo, Mensa, Dorado, Hydrus, Toucan, Apus, &c. The paucity of bright stars is relieved by the presence of the two remarkable objects variously known as the "Magellanic Clouds," "the Clouds of Magellan," and the "Nubeculae." These two objects are peculiar to the southern hemisphere, and have no counterpart in our northern skies. They are composed of stars, star-clusters and nebulae, and seem to form independent systems outside of the greater universe of stars.

On the opposite side of the pole from the Cross is the constellation *Eridanus*, the northern part of which is to be seen in our latitudes. Its most brilliant parts, however, are only visible in the south. Its most brilliant star, Alpha, is also known by the Arabic name of "Achernar," "the end of the river." Finally, between Argo and Eridanus is Columba, the Dove, immediately south of Lepus, the little group below Orion.

A number of these southern constellations such as Argo, Centaurus, Lupus, and Eridanus have been known from prehistoric times ;

but the majority have only been known and named since European civilisation reached the southern hemisphere. Considering the advantages of later astronomers as compared with the circumstances of the early star-gazers who named our northern star-groups, it cannot be pretended that they accomplished their work satisfactorily; for the southern constellations, speaking generally, are not only difficult to identify, but are inappropriately named and grouped.

The chief stars in the southern hemisphere are easily remembered, in the same way as those in the north—the Cross and Achernar are at different sides of the Pole; so are Argo and Scorpio. And with the march of the seasons their positions are constantly changing.

CHAPTER VIII.

SUN, MOON, AND PLANETS.

WE have now discussed the various constellations and the best method of recognising them and identifying their principal stars. These stars lie at immense distances from the Earth; they form the background of the motions of the bodies of the Solar System.

The ancient Greeks recognised seven bodies

which were clearly not stars—the Sun, the Moon, Mercury, Venus, Mars, Jupiter, and Saturn. All the stars which the ancients grouped into constellations were known to be fixed in position relatively one to the other. Sun, Moon, and planets were known to move round the starry sphere, and to have different motions. Indeed, the word "planet" is Greek for "wanderer." While the solar and lunar motions are regular, the planets obviously wander round the heavens.

The Zodiac.—We may briefly consider the apparent motions of the Sun and Moon, and of the various planets, and also the best method of identifying the "wandering stars." The ancients recognised the fact that Sun, Moon, and planets moved round the heavens within a belt of sky which they termed *the Zodiac*, and which passed through the twelve constellations, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces.

The Sun.—The position of *the Sun* in the heavens is not so obvious as that of the Moon and planets; but astronomers in prehistoric times were aware of the fact that the Sun moved round the sky in a path called the *ecliptic*, reaching right through the zodiacal constellations. In the chapters on the stars in their seasons we saw that some of the

zodiacal constellations such as Taurus and Gemini are high in the heavens, and others such as Scorpio and Sagittarius are low down and not far above the horizon. Here, then, we have the key to the seasonal changes. When the Sun in its apparent path is in the high constellations of the Zodiac it is summer; the orb of day is high above the horizon and is visible for a protracted period; when, on the other hand, the Sun is in Scorpio or Sagittarius it is winter. The Sun is low in the sky and is only visible for a comparatively short time. When the brilliant constellations of winter are on the meridian at midnight, the Sun is in the zodiacal constellations opposite, namely, the "summer star-groups," Scorpio and Sagittarius. In summer the Sun is in the winter constellations. The reason of this tilting of the ecliptic is the fact mentioned in the first chapter, namely, that the axis of the Earth is not perpendicular to the plane of its orbit, but inclined twenty-three degrees. At the spring equinox, in March, day and night are equal all over the Earth—at the poles and the equator. At this period both the poles are exposed to the Solar days in an equal degree; but with the gradual revolution of the Earth in its orbit the northern hemisphere is inclined more and more to the solar beams, and the southern hemisphere less and less. Gradually

spring passes into summer. At the summer solstice in June the days are much longer than the nights in the northern hemisphere, while in the southern the reverse state of things prevails. After June the period of daylight in the northern hemisphere gradually decreases until in September day and night are equal all over the globe. The axis of the Earth is again upright relative to the Sun; the northern hemisphere is tilted more and more away from the Sun as autumn passes into winter, until at the winter solstice it reaches its greatest inclination away from the sun—the reverse state of affairs being the case in the south. After the winter solstice the period of daylight gradually increases, as the Earth is tilted more and more towards the solar beams until the spring equinox in March, when day and night are equal all over the globe.

The result of this cycle of change is that in spring and autumn the Sun rises due east and sets due west; in summer it rises in the north-east and sets north-west, and is about eighteen hours above the horizon—just as is the case with the high constellations of the Zodiac, Taurus and Gemini; in winter it rises in the south-east and sets in the south-west, and is above the horizon for a comparatively short time, as in the case of the low constellations of the Zodiac, Scorpio and Sagittarius.

The seasons, then, are due to the inclination of the Earth's axis. But another cause is also at work, though in a very modified degree. The Earth's orbit is not a perfect circle, but an ellipse; therefore at one point of its orbit the Earth is closer to the Sun than at the other. In our northern winter the Earth is three millions of miles nearer than in summer. Here we have an apparent paradox—that the time of closest approach to the Sun is the time of greatest cold. When we consider the question, the apparent paradox soon disappears. In the northern hemisphere the lesser distance of the Sun modifies the rigours of winter, and its greater distance mitigates the warmth of summer. In the southern hemisphere, on the other hand, the conditions are reversed. The period of greatest heat occurs when the Sun is at its least distance, and that of greatest cold when it is furthest away. Thus the climate in the northern hemisphere is rendered more equable than that in the southern.

To the observer without a telescope the Sun can scarcely be described as an interesting object. When spots are numerous, at the sun-spot maximum, the larger ones are sometimes visible to the unaided eye through smoked glass. But the visibility of sun-spots to the unaided eye is a very rare occurrence.

With a small telescope provided with a dark eyepiece many interesting observations on spots—isolated and in groups—may be made. To the observer provided with such an instrument the Sun is a fascinating study.

The Moon.—The motion of the Sun round the heavens is only apparent. It is the Earth which moves along the ecliptic and causes the apparent motion of the orb of day. With *the Moon* the case is different. Alone of all the celestial bodies the Moon really revolves round the Earth. Its circuit of the zodiacal constellations represents a true motion. This circuit occupies 29 days and over 12 hours, roughly a month. In reality the Moon's period of revolution round the Earth is 27 days 7 hours. The difference between the real and apparent periods is due to the Earth's revolution round the Sun, carrying the Moon along with it.

The phases of the Moon have been noted from the earliest ages; they are due to the fact that the Moon is a dark body shining by reflected light. At "new Moon" the Earth, the Moon, and the Sun are in a straight line, with the Moon in the middle position. The Sun is shining direct on the side of the Moon which is turned away from the Earth, and our satellite is invisible. At "first quarter" we only see half of the Moon illuminated. It is then at the point of its orbit, midway between

"new Moon" and "full Moon." At full Moon the Sun, the Earth, and the Moon are in a straight line, with the Earth in the middle position. The Sun is shining directly on the Moon, and we see it fully illuminated, while at "last quarter" only half of the Moon is illuminated, as seen from Earth.

Owing to its eastward motion along the Zodiac, the Moon rises about 50 minutes later each day. This is the average amount of delay, but the amount varies; sometimes it is less than half an hour, sometimes an hour and a quarter. The difference depends on the angle which the Moon's path makes with the horizon; this angle is least in the constellation Pisces, visible in autumn. Hence we have the phenomenon of the "Harvest Moon," when our satellite rises less than half an hour later every evening.

There is much less moonlight in summer than in winter. At first this may seem to be due to the lengthened period of daylight—the moonlight not being required and consequently not noticed; such, however, is not the case. There is really less moonlight in summer than winter. This arises from the fact that before the Moon can be "full" and shining with complete radiance, it must be "in opposition" to the Sun; that is, situated in the diametrically opposite region of the sky.

In winter the Sun is passing through the lower zodiacal constellations, consequently the Moon at the full phase passes through the higher. The full Moon at midwinter is in the same situation as the Sun at midsummer. Thus in winter there is more moonlight than sunlight. In summer the conditions are reversed. The Sun is in the higher constellations; consequently the full Moon at midsummer occupies the place of the Sun at midwinter, and thus there is more sunlight than moonlight.

The Moon may be studied by means of the binocular, and even in a small telescope it is a wonderful spectacle.

The full phase of the Moon is the most useful to mankind, but it is not the most interesting to the astronomer. At that phase the Sun is shining direct on the Moon, and consequently the objects of the lunar surface cast no shadows. A view of the full Moon in a telescope is distinctly disappointing. A few days before the full phase useful observations may be made. The astronomer, however, studies the Moon at all its phases; in fact, it is only by long-continued observation that anything can be learned concerning our satellite.

When one looks at the Moon through a telescope—large or small—for the first time, the most striking feature is the rugged and mountainous character of the lunar surface.

The surface is diversified by great grey plains, which were once supposed to be seas, and mountainous uplands, comprising ranges of hills and mountains, and great numbers of walled plains and volcanic craters. These volcanic craters are by far the most numerous objects on the Moon. Volcanic action seems to have been much stronger on our satellite than our Earth—relatively to size. However, this action seems to be now practically extinct, and the Moon is generally believed to be a dead world. Professor Pickering's studies indicate the possibility that a very thin atmosphere does exist, and that there is a rudimentary vegetation. But, even if this be so, we are correct in regarding the Moon as dead.

The Planets.—There can be little difficulty in identifying the principal planets—Venus, Mercury, Mars, Jupiter, and Saturn. Of the seven chief planets of the Solar System outside of our own world, only these five are visible to the unaided eye. Uranus is practically invisible without the aid of a telescope, and Neptune absolutely so.

Absolutely the larger planets are divided into two groups according to size—the Inner Planets, comparatively close to the Sun, Mercury, Venus, the Earth, and Mars, comparatively small in size ; and the Outer Planets—beyond the ring of minor planets—Jupiter,

Saturn, Uranus, and Neptune, planets of large size. At present, however, we are discussing the heavens as they appear to us; we are inhabitants of one of these inner planets, the Earth. Consequently the planets appear to us to be divided into two groups—those which revolve round the Sun in orbits within the Earth's pathway, and those revolving without. These two groups are generally spoken of as the "inferior" and "superior" planets. In reality the more correct names are, the interior and exterior planets. The interior planets are Mercury and Venus, and the exterior planets Mars, Jupiter, and Saturn—Uranus and Neptune being beyond the reach of the unaided vision.

The two groups of planets have many points of difference. The interior planets, Venus and Mercury, are never seen far from the Sun. They can never be in "opposition"; that is to say, they never rise at sunset, reach the meridian at midnight and set at sunrise. Neither is ever seen on an absolutely dark sky; they seem to oscillate to and fro on either side of the orb of day. The exterior planets on the other hand are to be seen in all parts of the heavens; they may be in "conjunction," invisible in the solar beams, or in "opposition," on the meridian at midnight and visible all night. Thus there are many more opportunities for observing the exterior

planets and their motions among the stars. These motions are much less simple than those of the Sun and Moon. The motion of the Sun along the ecliptic is simply the Earth's motion reflected in the heavens; the Moon's circuit of the Zodiac is simply the actual revolution of the Moon round our world. But the planetary motions are a combination of real and apparent movements. The Earth is a planet, and in motion round the Sun; the planets are also moving round the Sun. Hence the Earth's motion is partly reflected in the irregularities of the planetary motions. Thus the planets are sometimes apparently moving from west to east; sometimes from east to west. Sometimes they appear almost stationary. It is, however, no part of our present purpose to enter into a discussion of the planetary motions and their irregularities, which have attracted the attention of astronomers and mathematicians in all ages.

Venus is the most brilliant planet—"the evening star" and "the morning star," the "Hesperus" and "Phosphorus" of the Greeks. From very early times the identity of the morning star and the evening star has been recognised. The late Professor Schiaparelli suggests that it was recognised so long ago as the epoch of the Book of Job; he believes "Mazzaroth in its season" to refer to

the periodical appearances of Venus. Be this as it may, the motions of Venus have been familiar to mankind from the earliest ages.

Venus is said to be at superior conjunction when the Earth, the Sun, and Venus are in a straight line, with the Sun in the middle. Venus, owing to its position within the Earth's orbit, exhibits phases similar to the Moon, and at this time it is fully illuminated, but is lost in the rays of the Sun. Then the planet emerges from the sunlight as "evening star." When it reaches the position known as "greatest elongation east" of the Sun, the disc seen through a small telescope is fully illuminated like the Moon at the quarters. As Venus draws nearer to the Earth the disc increases in size, but the illuminated portion decreases until the planet—now a dwindling crescent—is again lost in the rays of the Sun at the position known as "inferior conjunction." This position is analogous to "new Moon." The planet is invisible, as its dark side is turned towards the Earth. Shortly after this it reappears as a "morning star"; it is at first a thin crescent, increasing in size until it reaches the position known as "greatest elongation west." It is now at its best position for observation as a morning star. Seen through the telescope the disc becomes smaller and more fully illuminated, until it again

reaches "superior conjunction," and is lost in the solar rays. The interval from conjunction to conjunction—superior conjunction to superior conjunction, or inferior to inferior—is 584 days, and is known as the "synodic period" of Venus.

Venus at times is exceptionally brilliant, and the ignorant have from time to time regarded the planet as a return of the "star of Bethlehem," or as a portent. The phases of the planet are not visible to the unaided eye, but may be seen in a small telescope. These phases were discovered by Galileo three centuries ago with the newly-invented telescope. As a telescopic spectacle Venus is one of the most exquisite in the heavens, but owing to its thick atmosphere and the difficulty of observing it, little is known of its physical constitution.

Mercury passes through the same series of changes as Venus in a shorter time, its synodic period being 116 days. Like Venus, Mercury exhibits "phases," but these are not visible in the smallest telescopes. Mercury is very difficult of observation, and it is no small tribute to the skill and perseverance of the prehistoric astronomers that Mercury was known in those early times. The planet is never far from the Sun, and can only be seen at its elongations as morning or evening star. Even at these periods it is difficult to observe,

and is only to be seen when the horizon is absolutely clear and free from clouds. It is recorded that Copernicus never succeeded in seeing the planet, although he often tried; the explanation of his failure being that he lived on the banks of the Vistula, where the horizon is never free from the mists which rise from the river.

The exterior planets—Mars, Jupiter, and Saturn—are to be seen in all parts of the Zodiac. None of them are so bright as Venus, but all are very noticeable. It is impossible to mistake or confuse them. Jupiter, generally the superior of Mars, shines with a clear steady yellow light; at times, however, Mars at its near approaches to the Earth is equal to Jupiter in brilliance. It shines with a steady fiery red light, from which peculiarity it was termed "the planet of war" by the ancients. Saturn, fainter than Mars or Jupiter, is equal in brilliancy to a star of the first magnitude; it shines steadily with a dull yellow light. All three planets are to be seen in "opposition" to the sun when they rise at sunset and set at sunrise; and as they make their nearest approaches at opposition, they have been closely studied both in telescopic and pre-telescopic times.

The synodic period of Jupiter—from conjunction to conjunction or opposition to oppo-

sition—is 399 days, and of Saturn 378 days. Thus the farther off a planet is, the shorter is its synodic period. With Mars the case is different; the synodic period is 780 days, over two years. Mars is much closer to the Earth than Jupiter and Saturn, and its apparent motion is more complex. Oppositions of Mars, too, vary greatly in brilliance. The orbit of Mars is very elliptical in comparison with other planetary orbits. The pathways of Mars and the Earth approach nearest at the point occupied by the Earth about the end of August, and they diverge most at the point occupied by our world in February. Hence when Mars is in opposition in autumn it is very bright, and in spring much fainter. This, however, is somewhat modified by the fact that in spring the planet is in the high zodiacal constellations, and in autumn in the low star-groups. Favourable oppositions, and also unfavourable, recur at intervals of about fifteen years. Thus there were very favourable oppositions, when the planet was very brilliant, in 1877, 1892, and 1907, and unfavourable appearances in 1886, 1901, and 1916.

A small telescope will show the satellites of Jupiter and the ring of Saturn. It has been alleged that the satellites of the former planet have been seen with the unaided eye, but the evidence is far from conclusive. In a small

telescope, however, they are easily seen, and form a beautiful telescopic spectacle. A small instrument will, however, show no features on Mars; a good telescope is required to show the surface-markings, while the famous "canals" are only to be seen with powerful instruments in favourable climates.

CHAPTER IX.

ASTRONOMICAL PHENOMENA.

UNDER the head of astronomical phenomena we include occurrences and appearances in the heavens—eclipses of the Sun and Moon, transits of Venus and Mercury, comets, meteors, the zodiacal light, and the Aurora Borealis. Such appearances attract a large amount of attention—more, perhaps, than is their due.

Eclipses and Transits.—These kindred phenomena are due to the fact that every body in the universe shining by reflected light casts a shadow into space in a direction opposite to the source of illumination. Thus the Earth casts a shadow, and similarly Venus, Mars, Jupiter, and the other planets cast shadows. The shadows cast by the Earth and the Moon are the cause of the phenomena known as solar and lunar eclipses. The Earth casts a

shadow, and when the Moon, the Earth, and the Sun are in a line, with our world in the middle, the terrestrial shadow which extends beyond the orbit of the Moon falls in the direction of our satellite. If the pathway of the Moon were exactly in the same plane or level as that of our world, it would pass through the shadow every time it reached the position known as full Moon.

As a matter of fact, however, the Moon's orbit is not exactly in the same plane as that of the Earth, and only occasionally an eclipse does take place. Sometimes a lunar eclipse is total—that is to say, the Moon is completely immersed in the Earth's shadow—and sometimes only partial, a portion of the disc remaining outside the true shadow. A total eclipse of the Moon is a very remarkable and beautiful phenomenon. As the Moon becomes gradually immersed in shadow, the illuminated portion becomes smaller and smaller until it completely disappears. The Moon is not, however, usually totally invisible. It generally assumes a dark copper-coloured hue, due to the refraction of sunlight through the atmosphere of the Earth. This is supposed to be due to the fact that the blue rays of the Sun are absorbed in traversing the atmosphere of the Earth, just as the sunset and sunrise skies assume a ruddy colour.

Eclipses of the Sun take place at new Moon, when the Earth, the Moon, and the Sun are in a straight line, the Moon occupying the middle position. Sometimes the shadow of the Moon falls on our planet. This shadow is much smaller than the shadow of the Earth, and it only covers a small strip of territory on the globe; to observers within this strip the Sun is for a few minutes totally eclipsed. Outside this strip there is a partial eclipse, part of the solar disc being obscured by the Moon. Occasionally an eclipse is partial without being total at any part of the Earth's surface. At times an eclipse is "annular," when the Moon is at the farthest point of its orbit and does not appear large enough to cover the Sun. At such times we are an "annulus" or ring of light round the Moon's disc. Of these three kinds of eclipses only total eclipses are useful to astronomers. This is owing to the fact that at such times the disc of the Moon appears large enough to cover the Sun, but not large enough, fortunately for astronomical science, to hide from view the immediate vicinity of the orb of day.

Since the days of the early Chaldeans astronomers have been familiar with a period by which the recurrence of solar and lunar eclipses can be predicted. This is known as the *Saros*. Its length is 18 years 111 days. In the words

of an American astronomer, "At the end of this period the centres of the Sun and Moon return very nearly to their relative positions at the beginning of the cycle; also certain technical conditions relating to the Moon's orbit and essential to the accuracy of the saros are fulfilled." Thus a total solar eclipse took place on May 17, 1882; it recurred on May 28, 1900; and again on June 8, 1918. Eclipses, however, do not recur on the same part of the Earth's surface; hence at any given place total solar eclipses are very rare. There has not been a total solar eclipse in the United Kingdom since 1724, and there will not be one visible until 1927. For those who have never seen a total eclipse, the following description by an American writer, Mrs. Todd, is worth reading, as illustrating the magnificence of the spectacle: "With frightful velocity the actual shadow of the Moon is often seen approaching, a tangible darkness advancing almost like a wall, swift as imagination, silent as doom. The immensity of Nature never comes quite so near as then, and strong must be the nerve not to quiver as this blue-black shadow rushes upon the spectator with incredible speed. Sometimes the shadow engulfs the observers smoothly, sometimes apparently with jerks; but all the world might well be dead and cold and turned to ashes. Often the very air seems

to hold its breath for sympathy; at other times a lull suddenly awakens into a strange wind, blowing with unnatural effect. Then out upon the darkness, gruesome but sublime, flashes the glory of the incomparable corona, a silvery, soft, unearthly light, with radiant streamers, stretching at times millions of uncomprehended miles into space, while the rosy flaming protuberances skirt the black rim of the Moon in ethereal splendour. It becomes curiously cold, dew frequently falls, and the chill is frequently mental as well as physical. Suddenly, instantaneous as a lightning flash, an arrow of actual sunlight strikes the landscape, and Earth comes to life again, while corona and protuberance melt into the returning brilliance."

Transits are kindred phenomena to eclipses. Only the interior planets, Mercury and Venus, are to be seen in transit across the Sun. Transits occur, like solar eclipses, when our world, Venus, and the Sun, or our world, Mercury, and the Sun are in a straight line. There is no eclipse, owing to the small apparent size of Mercury and Venus; we merely see black discs as spots crossing the face of the Sun.

Transits of Venus occur in pairs, separated by intervals of eight years; and the pairs are separated by intervals of 105½ and 121½ years. There were transits in 1631 and 1639, 1761

and 1769, 1874 and 1882; and the next pair will take place in 2004 and 2012. Transits of Mercury are much more frequent.

Comets and Meteors.—These kindred celestial bodies have attracted the attention of mankind from the earliest ages. Among the ancients and to the people of the Middle Ages comets were a source of terror, and were believed to be terrible portents of wars, famines, and other national disasters.

In the present day these feelings have given place to wonder and admiration. Of all celestial phenomena, comets attract the greatest and most widespread attention. In our present knowledge we may divide comets into two classes—those which have been proved to revolve round the Sun and whose returns can be predicted, and those comets which have not been demonstrated to be members of the Sun's family. To the first class belongs the famous comet of Halley, whose last appearance in 1910 fell so far short of popular expectation; and also the faint comet of Encke, which returns every three years, and others. Most of the periodic comets are faint, and do not attract attention even when visible to the unaided eye.

The brilliant comets of 1811, 1843, and 1858, and other notable comets of the last century, may or may not belong to the Solar System;

if they revolve round the Sun, they must do so in enormously long periods. Thus a bright comet appears, unexpectedly as a general rule ; its coming has not been predicted. This was the case with the only bright comet of recent years, the "great Daylight Comet" of January 1910.

Meteors or shooting-stars are generally believed to be the products of the dissolution of comets—minute particles of matter which become ignited on entering the Earth's atmosphere. They travel in ones, twos, threes, and in swarms or streams. The chief streams are the Leonids, Perseids, Lyrids, Andromedids, &c. ; but there are many others, and not a night passes without several meteors shooting across the sky.

The study of meteors is one peculiarly adapted for the observer without a telescope ; indeed, in this branch of astronomy both telescope and binocular are useless. All our knowledge of meteors is due to observation of meteors—time of flight, length of path, brilliance, colour, &c.—by the unaided eye ; and the greater part of the work in this branch of astronomy has been accomplished by one non-professional astronomer—Mr. W. F. Denning of Bristol.

A remarkable fact in connection with meteors is that from midnight to dawn is a much more

favourable time for observation than from sunset to midnight. The explanation is that more meteors meet the Earth than overtake it, and as Mr. Maunder remarks—" the Earth has its sunrise point in front as it moves forward in its orbit, its sunset point behind."

The Zodiacal Light.—This is a phenomenon which is much better seen in tropical than in temperate regions, but it is occasionally observed in Europe. A pearly glow is sometimes noticed in the spring to spread over a portion of the sky where the Sun has disappeared. In autumn the same phenomenon is also to be seen before sunrise. It is in tropical regions, however, that it is seen in its full glory. Instead of being seen like a cone, as in our latitudes, it appears as a band of light, and the portions near to the Sun seem as brilliant as the Galaxy. The exact nature of the zodiacal light has long been more or less of a mystery. The general idea among astronomers is that it is due to diffused dust, in all probability meteoric matter which forms an outer appendage to the Sun. Opposite in the heavens to the Light is a much fainter phenomenon known by its German name of " the Gegenschein," or counter-glow. Probably it is also of meteoric composition.

The Aurora Borealis.—This phenomenon, closely connected with the magnetism of the

Earth, is one of the most striking of celestial spectacles. Properly speaking, the aurora should perhaps be classed among atmospheric phenomena, but its close connection with the sun-spot period renders it more directly akin to the heavens proper.

The Aurora Borealis—the "Northern Lights"—is a regular phenomenon in the Arctic regions, and is often visible in the Shetlands and Orkneys, the north of Scotland, and Northern Europe. In lower latitudes the aurora is a rare spectacle, and attracts a great deal of attention. It consists of streamers, bands, curtains, and rays of light of varying tints and different degrees of brilliancy. These tremble and shoot up and down the sky with startling effect; hence the popular name of the aurora—"the Merry Dancers."

In lower latitudes aurorae should be looked for more particularly when spots are numerous on the solar disc. Great storms in the Sun are generally accompanied by magnetic disturbances and brilliant auroral displays on the Earth. The nature of the connection has not been fully explained, but of its reality there is no doubt.

In this chapter particular attention has been given to these astronomical phenomena which are of comparatively rare occurrence—the appearance of bright comets, meteoric dis-

plays, eclipses of the Sun and Moon. These phenomena never fail to awaken the curiosity and interest of the average man. It is well that they should; and yet it is necessary to remember that wonderful as are eclipses, remarkable as are meteoric showers, far more wonderful, far more marvellous are the ordinary facts which astronomy teaches us, far more awe-inspiring is a thoughtful glance into the immeasurable heavens. The marvellous power and energy of the Sun, the never-failing regularity of the Moon and planets in their eternal revolution, the vast distances and spaces, the calm shining of the changeless stars —these are marvels visible to us daily and nightly, and we heed them not. Familiarity gives rise, if not to contempt, at least to indifference. As Emerson has truly said: "If the stars should appear one night in a thousand years, how would men believe and adore, and preserve for many generations the remembrance of the City of God which had been shown."

BIBLIOGRAPHY.

The Constellations and How to Find Them. By William Peck, F.R.A.S. A series of monthly charts showing the chief stars and their position in the heavens. A useful guide for the beginner. (Gall & Inglis, Edinburgh.)

Star-Groups. By J. Ellard Gore, F.R.A.S. A more advanced book than the last-named. There is a map for each constellation, and the individual stars are plainly marked. Probably the best book of its kind. (Crosby, Lockwood & Co., London.)

Astronomy Without a Telescope. By E. Walter Maunder, F.R.A.S. A work descriptive of the heavens as seen with the unaided eye. The first part of the book describes the constellations season by season. The second and third parts describe exercises and practical observations. An excellent work. ("Knowledge" Office, London.)

A Popular Introduction to Astronomy. By Rev. A. C. Henderson. A little book by an amateur astronomer, who has worked out for himself the exercises in astronomy which he describes. (Manson, Lerwick, Shetland.)

A New Astronomy. By Professor D. P. Todd. More advanced than the preceding books and less purely descriptive of the heavens, as they are. This work is most helpful to those beyond the stage of merely looking at and identifying the stars. (Sampson, Low & Co., London.)

Astronomy for Amateurs. By Camille Flammarion. This book is rather an astronomical survey than a guide to the heavens; but it contains some chapters bearing on this branch of the subject. (Fisher Unwin, London.)

INDEX.

PRINTED IN GREAT BRITAIN AT
THE PRESS OF THE PUBLISHERS.